NASA/CR—2005-213334

Gen 2.0 Mixer/Ejector Nozzle Test at LSAF June 1995 to July 1996

L.D. Arney, D.L. Sandquist, D.W. Forsyth, and G.L. Lidstone
The Boeing Commercial Airplane Company, Seattle, Washington

February 2005

The NASA STI Program Office . . . in Profile

Since its founding, NASA has been dedicated to the advancement of aeronautics and space science. The NASA Scientific and Technical Information (STI) Program Office plays a key part in helping NASA maintain this important role.

The NASA STI Program Office is operated by Langley Research Center, the Lead Center for NASA's scientific and technical information. The NASA STI Program Office provides access to the NASA STI Database, the largest collection of aeronautical and space science STI in the world. The Program Office is also NASA's institutional mechanism for disseminating the results of its research and development activities. These results are published by NASA in the NASA STI Report Series, which includes the following report types:

- TECHNICAL PUBLICATION. Reports of completed research or a major significant phase of research that present the results of NASA programs and include extensive data or theoretical analysis. Includes compilations of significant scientific and technical data and information deemed to be of continuing reference value. NASA's counterpart of peer-reviewed formal professional papers but has less stringent limitations on manuscript length and extent of graphic presentations.

- TECHNICAL MEMORANDUM. Scientific and technical findings that are preliminary or of specialized interest, e.g., quick release reports, working papers, and bibliographies that contain minimal annotation. Does not contain extensive analysis.

- CONTRACTOR REPORT. Scientific and technical findings by NASA-sponsored contractors and grantees.

- CONFERENCE PUBLICATION. Collected papers from scientific and technical conferences, symposia, seminars, or other meetings sponsored or cosponsored by NASA.

- SPECIAL PUBLICATION. Scientific, technical, or historical information from NASA programs, projects, and missions, often concerned with subjects having substantial public interest.

- TECHNICAL TRANSLATION. English-language translations of foreign scientific and technical material pertinent to NASA's mission.

Specialized services that complement the STI Program Office's diverse offerings include creating custom thesauri, building customized databases, organizing and publishing research results . . . even providing videos.

For more information about the NASA STI Program Office, see the following:

- Access the NASA STI Program Home Page at ***http://www.sti.nasa.gov***

- E-mail your question via the Internet to help@sti.nasa.gov

- Fax your question to the NASA Access Help Desk at 301–621–0134

- Telephone the NASA Access Help Desk at 301–621–0390

- Write to:
  NASA Access Help Desk
  NASA Center for AeroSpace Information
  7121 Standard Drive
  Hanover, MD 21076

NASA/CR—2005-213334

Gen 2.0 Mixer/Ejector Nozzle Test at LSAF June 1995 to July 1996

L.D. Arney, D.L. Sandquist, D.W. Forsyth, and G.L. Lidstone
The Boeing Commercial Airplane Company, Seattle, Washington

Prepared under Contract NAS3–27235

National Aeronautics and
Space Administration

Glenn Research Center

February 2005

Acknowledgments

The authors would like to thank Mary Jo Long-Davis from NASA Glenn for her support through NASA contract NAS3–27235. We would like to acknowledge the help and support provided to the Boeing test team by all the members of the various nozzle teams—model, aero, acoustic, and ITD. These teams were all actively involved in the decision process at LSAF and analysis of the test results. In addition, several team members from Pratt & Whitney and General Electric provided on-site test support and made sure the model hardware arrived on-time and in good working condition. We would also like to acknowledge the efforts of the Boeing LSAF test crew. The length of the test (14 months), the required data accuracy, and the frequent changes to the test plan all presented difficult challenges.

Document History

This research was originally published internally in April 1997.

Note that at the time of writing, the NASA Lewis Research Center was undergoing a name change to the NASA John H. Glenn Research Center at Lewis Field. Both names may appear in this report.

Available from

NASA Center for Aerospace Information
7121 Standard Drive
Hanover, MD 21076

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22100

Available electronically at http://gltrs.grc.nasa.gov

Executive Summary

The Gen 2.0 Nozzle Test was successfully run in Boeing's Low Speed Aeroacoustic Facility (LSAF) from June 1995 through July 1996. This document summarizes the results of this test.

The test of the Generation (Gen) 2.0 High Speed Civil Transport (HSCT) model nozzle in the Low Speed Aeroacoustic Facility at Boeing was done to get simultaneous noise and thrust measurement for two dimensional (2D) rectangular noise suppressor nozzles. Figure 1 shows the model installed in the LSAF test section.

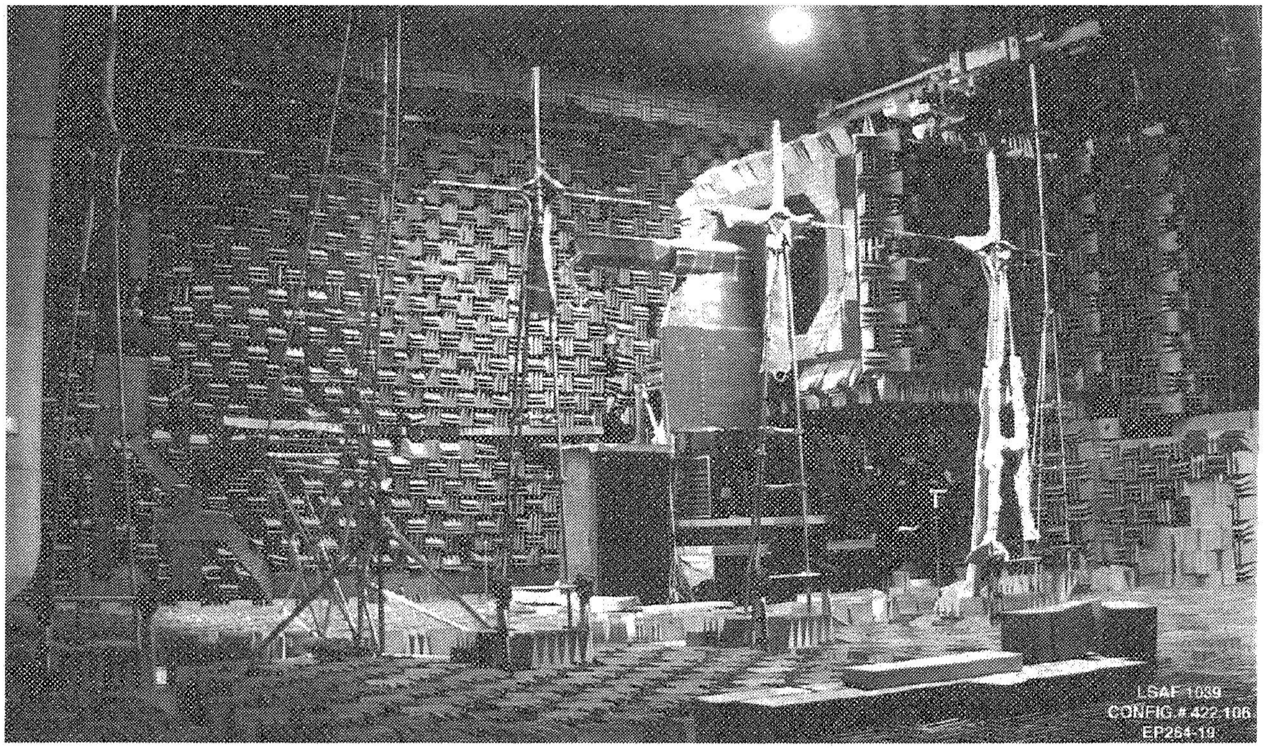


Figure 1, Gen 2.0 Model Hardware Installed in LSAF Test Cell

Concurrent measurement of noise and thrust were made at realistic suppressed mode takeoff conditions. The wind tunnel simulated aircraft conditions for the ejector up to Mach 0.32 forward flight velocity while the jet flow simulator provided air to the mixer that matched the current engine cycles for both pressure and temperature. A translating microphone array and assorted fixed microphones collected noise data for the mixer/ejector system at cutback and sideline over the range of polar angles of interest (50°–145° relative to inlet axis) to simulate FAR36 flyover conditions.

Pressure instrumentation located throughout the model was used to measure the flow conditions within and around the mixer/ejector system. Additionally, surveys of the nozzle exhaust were done with a 5 hole cone probe/thermocouple system for key configurations. These surveys provided exit velocity and temperature (and therefore, mixedness) information within the mixer/ejector system.

Two different ejector models were used in the Gen2 test. The first model, called the Down Stream Mixer (DSM), was made by P&W and represents the rotating (and translating) chute system where the mixer retracts when not in use. The second model, called the Hot Aeroacoustic Model (HAM), was made by GE and represents the Fixed Chute Nozzle (FCN) concept. Here the mixer remains fixed in the primary stream at all times. Figures 2 through 4 compare the test model to the full–scale product concept. Each system really represents a family of mixers designed to fit a common model scale 2D ejector nozzle.

Each member of the family of mixers represents different variations from two "standard" mixers (best–aero and vortical). By testing the variations in the same ejector, weighing both the noise and performance, the design path to the "best" mixer for this type of ejector becomes more apparent.

The inner walls of the ejector were designed to accept various acoustic liners as well as hardwall liners. The hardwall liners were used as an acoustic datum and performance baseline.

The following liner variations were tested with the DSM:

- Hardwall liner as an acoustic and aero reference
- 3 bulk absorber liners, 13mm SiC foam, 7mm SiC foam, 13mm foam metal.
- 2 "single degree–of–freedom" (open cell or SDOF) liners, 13mm and 7mm. The 13mm deep cells were squares roughly 10mm on a side using the standard perf sheet trays. The 7mm deep SDOF liners had 7mm honeycomb cells silver brazed to a felt metal face sheet.

For the best–aero mixers, the following variations were tested:

- Suppressor area ratio (SAR) was varied from 2.3 to 2.9 with the nominal ratio being 2.5 SAR.
- Mixer lobe penetration (the relative height of the mixer lobes to the height of the ejector) was varied from 85% to 100% with the nominal lobe height being 92.5%.
- Mixer area ratio (MAR) was varied from 0.85 and 1.00 by adjusting the angle of the ejector flaps. A nozzle converging at 0.9 MAR generally proved to be the best noise/thrust trade for these mixers.

For the vortical mixers a reduced set of variations were tested:

- Only two SAR's (2.5 and 3.38) were tested.
- The penetration variation was achieved using "flapper valves" at the top of the primary chutes.
- Mixer area ratio (MAR) was varied the same way as the best–aero mixers.
- The acoustic trays are the same for this family of mixers, but only 13mm SiC, 7mm SiC and hardwall liners were tested with the vortical mixers.

In addition to the DSM, tests were done with the Gen 1.5 Hot Acoustic Model (HAM) ejector using new Gen 2.0 best–aero type mixers. The HAM model differed from the DSM with a higher aspect ratio, 1.5 vs 1.17, and a longer shallower inlet design. The major reason for testing the HAM nozzle was that previous testing showed a sideline noise benefit in higher aspect ratio ejector nozzles. A previous vortical mixer was added to the HAM test as an experimental control. The Gen 1.5 NRA mixer had been tested in GE's Cell 41 and allowed a direct comparison between the facilities.

Acoustic liners tested with the HAM model included:

- Hardwall
- 2 bulk liners, 13mm SiC foam, and 13mm foam metal.
- 1 "simulated hardwall" configuration – 13mm foam metal with thin sheet metal blocking the perf–plate pores

For the best–aero mixers, the following variations were tested:

- Suppressor area ratio (SAR) was varied from 2.5 to 2.9 with the nominal ratio being 2.5 SAR.
- Mixer lobe penetration (PEN) was varied from 85% to 100% with the nominal lobe height being 92.5%.
- Mixer area ratio (MAR) was varied from 0.90 and 0.95 by adjusting the angle of the ejector flaps. A nozzle converging at 0.95 MAR generally proved to be the better noise/thrust trade for these mixers.

For the HAM vortical mixer a reduced set of variations were tested:

- Only one SAR (2.8) was tested.
- Only one penetration (92.5) was tested.
- Mixer area ratio (MAR) was varied the same way as the best–aero mixers.
- The acoustic trays are the same for this family of mixers, but only 13mm SiC foam metal and simulated hardwall were run with the HAM vortical mixer.

Summary

A test of a series of Gen 2.0 HSCT small scale nozzles has been conducted at the Boeing Low Speed Aeroacoustic Facility (LSAF). Concurrent measurement of noise and thrust were made at realistic suppressed mode takeoff conditions. The wind tunnel simulated flight conditions from static to Mach 0.32 forward speed. The jet flow simulator provided primary air into the mixer that matched the current engine cycles for both pressure and temperature. A translating microphone array collected acoustic data at both cutback and sideline angles with a range of azimuthal angles from 20 to 90 degrees (90 degrees being overhead). The microphone array translated from 65 degrees in the forward arc to 145 degrees in the aft arc. Static pressure instrumentation was located throughout the mixer, ejector, and along the external surfaces. Total pressure data were obtained to evaluate the quality of the flow entering the mixer inlets and the exit of the mixer secondary. Additionally, surveys of the nozzle exit were done with a 5 hole cone probe/thermocouple system for key configurations. These surveys provide exit velocity and temperature (and therefore, mixedness) information within the mixer/ejector system.

Figure 5 summarizes the test data acquired at LSAF. Thrust vs noise level for several of the mixer/ejector systems tested are shown for the key cutback and sideline design conditions. The best overall aero/acoustic mixer/ejector system tested is indicated on the plot. The highlighted configuration (13mm SiC treated mixer 8 with chevrons and long ejector) achieved the Gen 2 objective of maintaining the low noise of the Gen 1.5 NRA mixer while improving the thrust performance of the nozzle to acceptable levels.

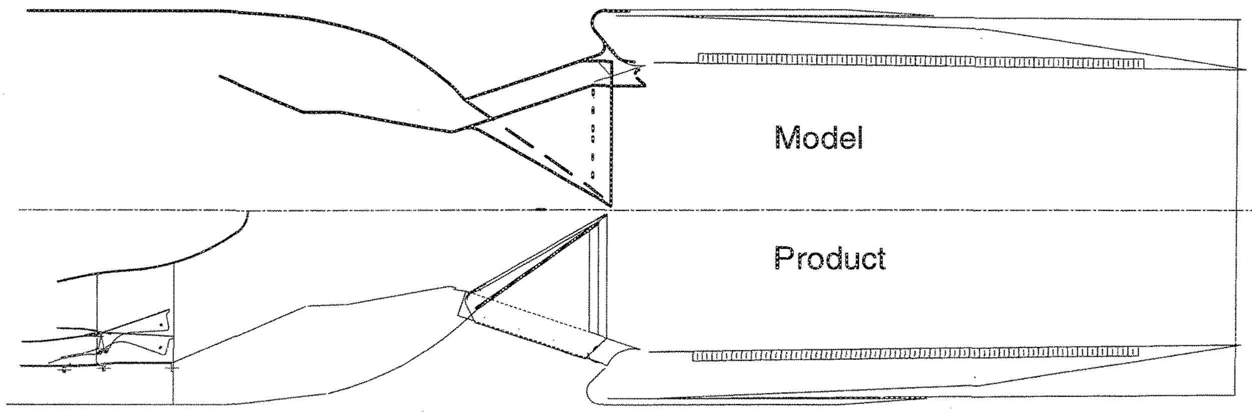


Figure 2, DSM Rotating Chute Model Compared to Product DSM Rotating Chute

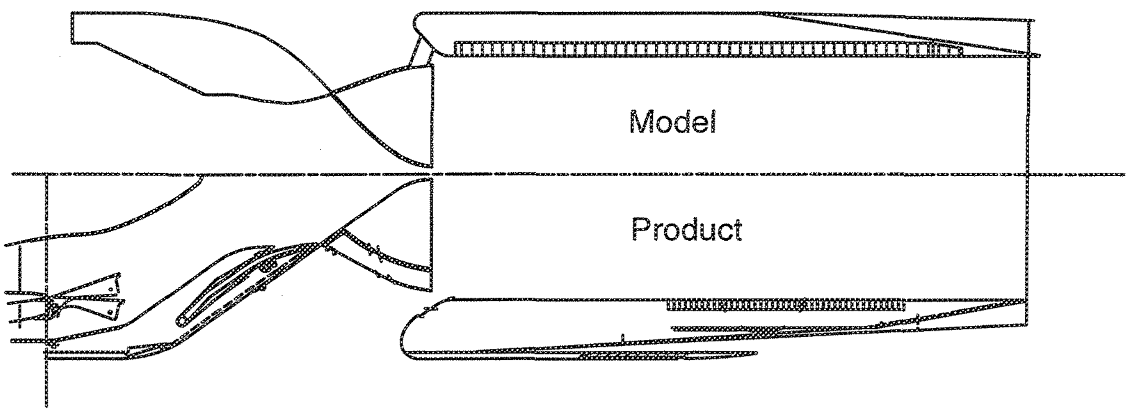


Figure 3, DSM Best Aero Model Compared to Product Translating Chute

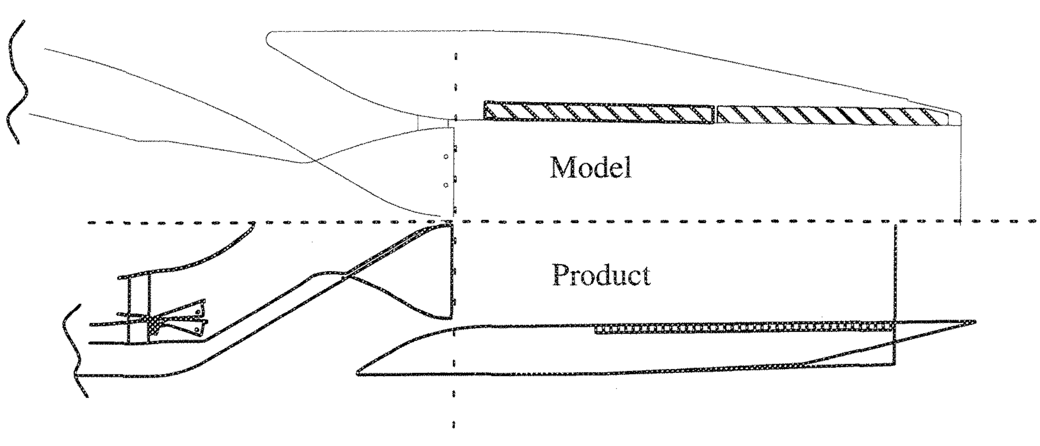


Figure 4, HAM Best Aero Model Compared to Product FCN

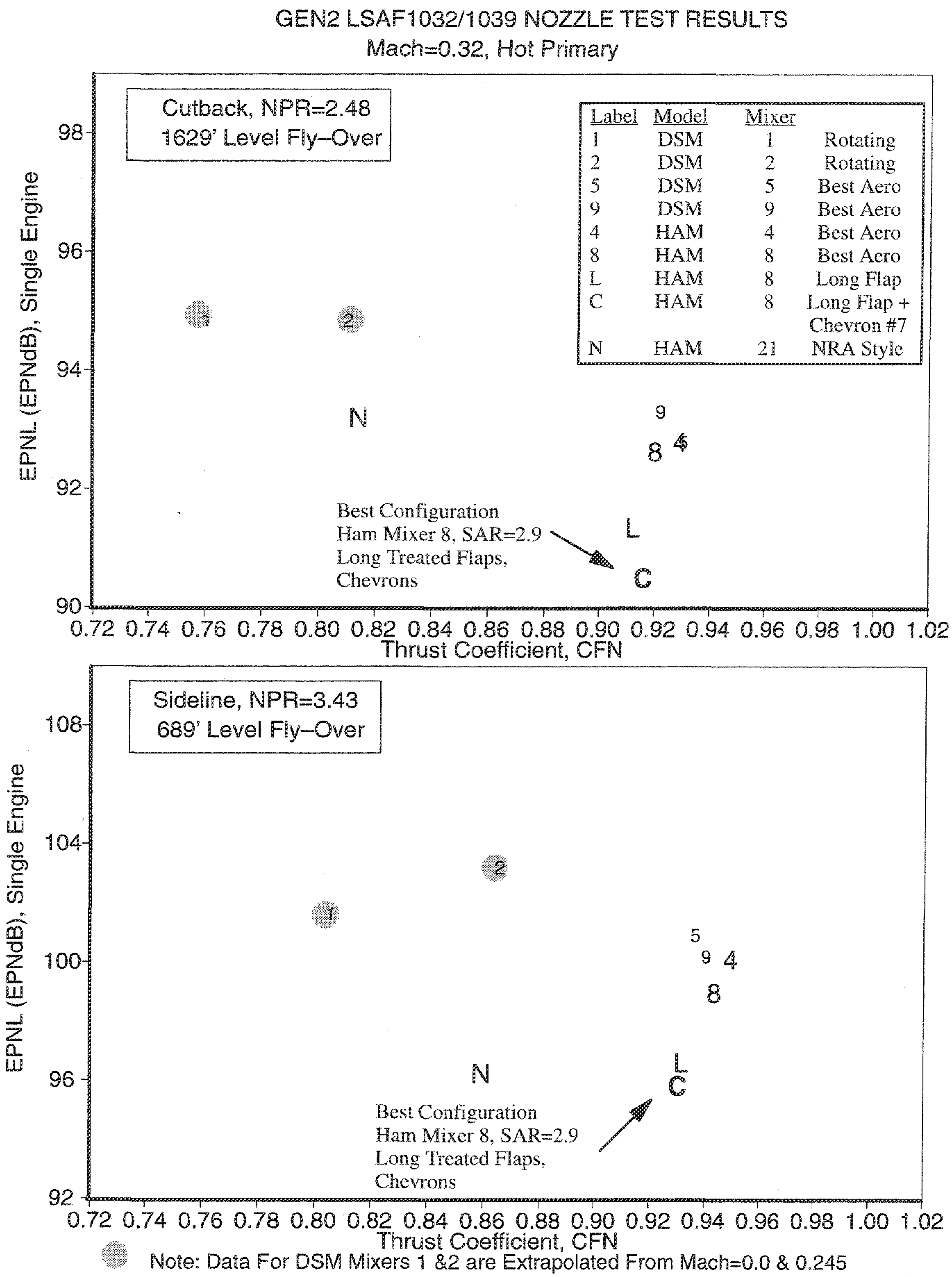


Figure 5, Overall Test Results, Mach=0.32, Hot Primary

Table of Contents

1.0 Test Facility

The Gen 2.0 Nozzle Test was conducted in the Boeing Low Speed Aeroacoustic Facility (LSAF). LSAF combines a large (65 feet long x 75 feet wide x 30 feet high) anechoic test chamber with a 9 x 12 foot free jet wind tunnel. This allowed simulation of forward flight speed up to Mach 0.25. Acoustic instrumentation included a traversing azimuthal microphone array at 15' sideline with additional free standing microphones to augment the array measurements, and a traversing elliptic mirror for noise source location. During the test, maximum flight Mach number was increased to 0.32 by modifying the contours of the free jet nozzle to a smaller exit area (from 9 x12 feet to 7 x 10 feet). The LSAF test cell configured with the DSM model is pictured in Figure 1.1. This figure shows the facility with the original 9 x 12 foot free jet. Figures 1.2 and 1.3 show the layout of test cell in plan view and end view respectively. Figure 1.4 illustrates the original Mach=0.245 tunnel free jet exit with the new Mach=0.32 free jet exit insert.

An Isometric view of the Monopod structure is shown in Figure 1.5. On top of the monopod is the six component E3 balance and the 3800 Jet Flow Simulator. The Jet Flow Simulator has an on board burner and can provide air to the model up to 30 lbm/sec (Cold) and up to 1700°F.

In order to isolate the forces acting upon the facility support structure from the forces acting upon the model, a series of drag tare runs were done. Figure 1.6 illustrates the facility drag tare and the nozzle drag tare hardware configurations. The HAM model is shown, but the same tares were done with the DSM hardware. The facility drag tare accounts for all the wind–on forces acting upon only the facility support structure. The nozzle drag tare accounts for all the wind–on forces acting upon the facility support structure and on the external surfaces of the nozzle.

A flow tube was used to calculate the flow through the secondary inlets of the DSM model (Figure 1.7) The tube attached to the back of the DSM nozzle hardware and was supported with chains from the ceiling and cables to the floor. A total pressure/total temperature rake near the flow tube exit was used to calculate the total mass flow through the ejector. The measured primary mass flow was subtracted from this, leaving the secondary mass flow. The secondary mass flow was then correlated to the inlet pressures, so the mass flow could be calculated with the flow tube removed. The flow tube was not available to calibrate the flow through DSM mixer 1. The flow tube was tried with mixer 2, but for a number of reasons the data was not useable. For these 2 mixers a backup method using existing instrumentation in the mixer and estimated area was used. The backup airflow calculation was done for all the DSM mixers and is reported as parameter ws2 in the data output. For the HAM mixers, an inlet total pressure rake was used to calculate the secondary mass flow.

While the test was in progress, the facility developed a traversing exit probe system to measure the flow conditions internal to and exiting the mixing duct. Four different probe configurations, described in Table 1, were tested. Because of its ability to measure all the pertinent parameters required to calculate velocity almost all of the exit probe testing was done with the 5 hole probe w/ thermocouple (Figure 1.8). To improve the accuracy of the 5 hole probe measurements, the 5 hole probe system was calibrated in the Boeing Flight Simulation Chamber, FSC. This calibration data was used to determine the velocity profiles. Reference 1 documents the 5 hole probe calibration.

Figure 1.1. LSAF Facility, Photo.

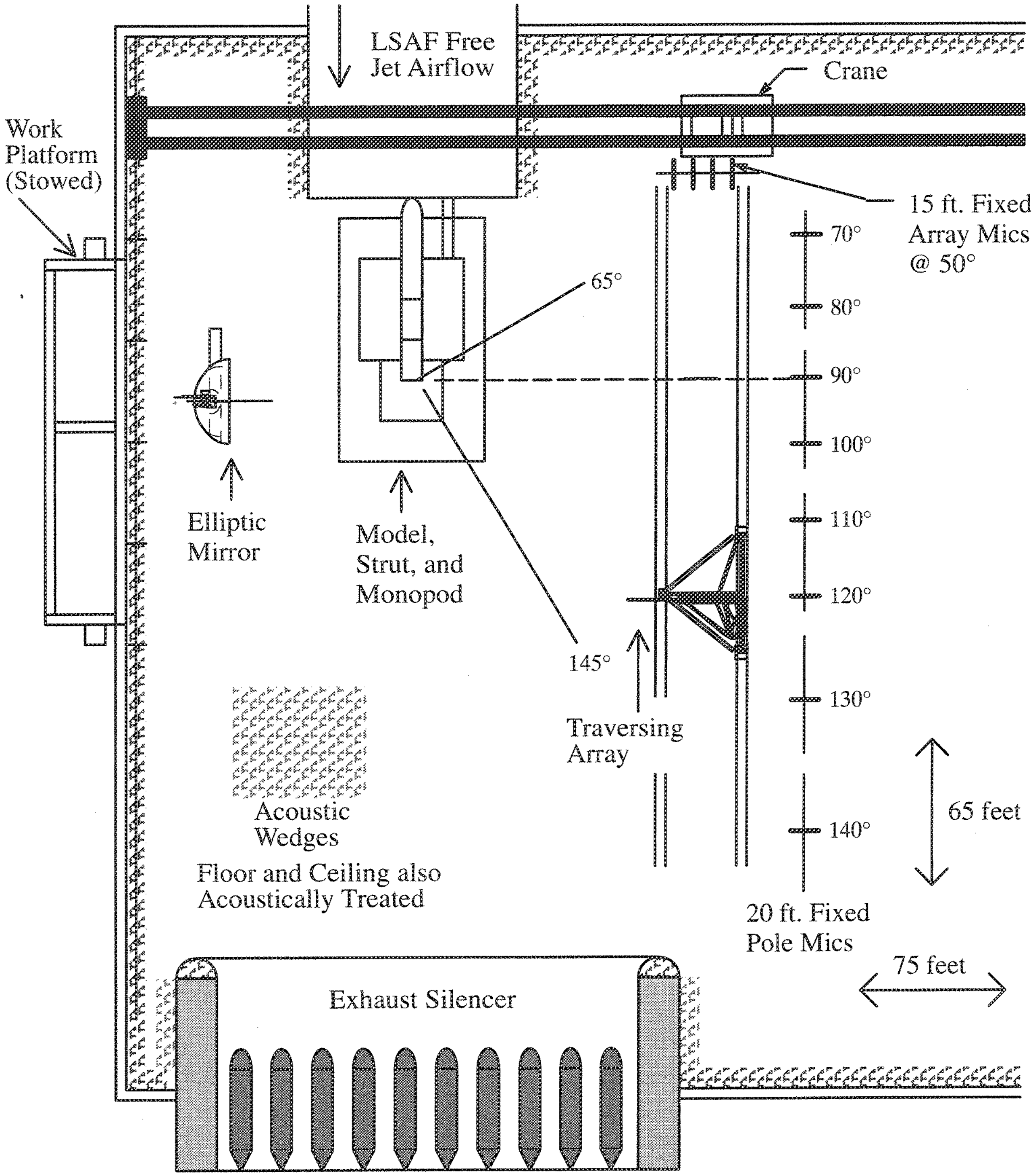


Figure 1.2 LSAF Test Cell – Plan View (not to scale).

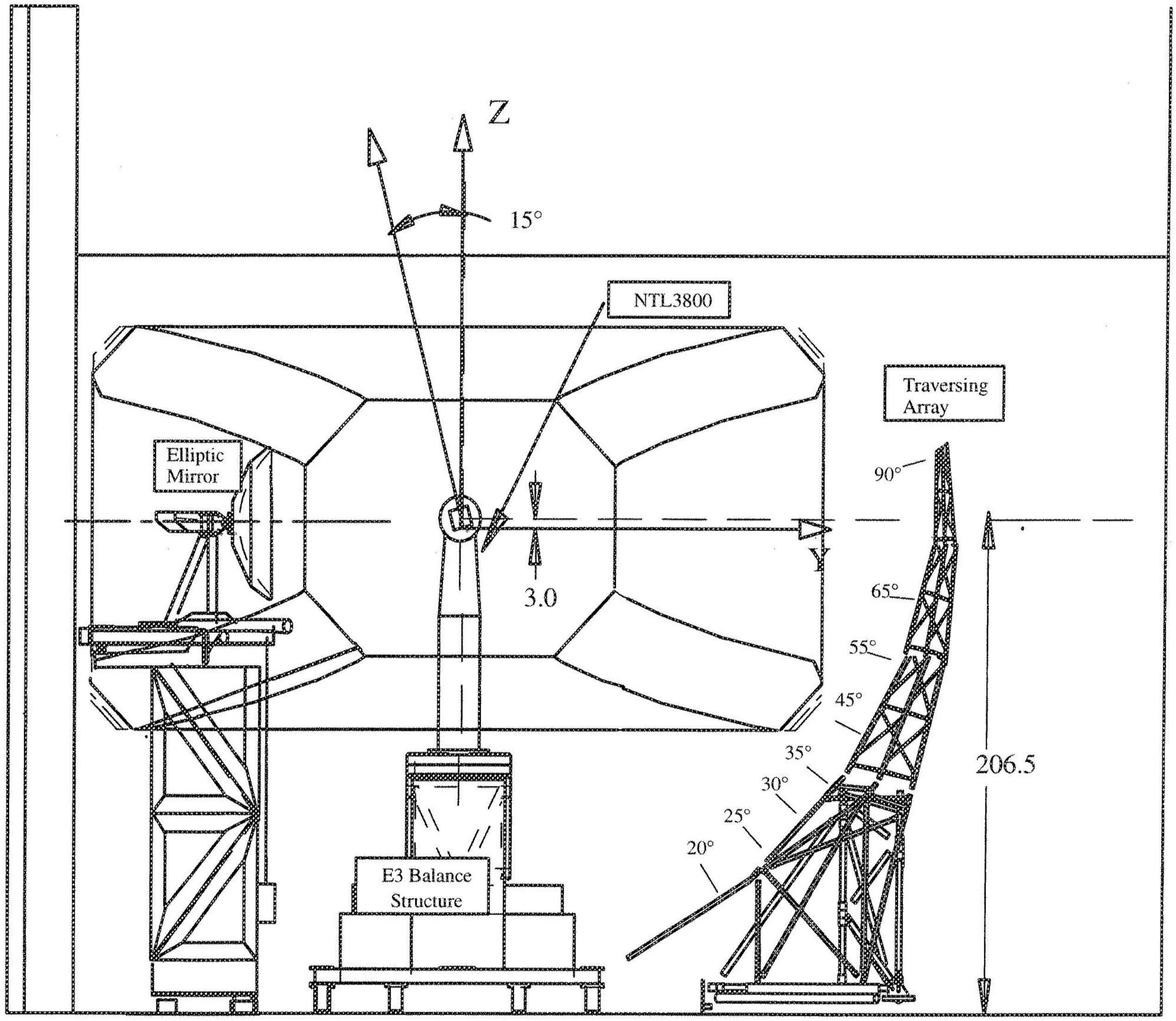


Figure 1.3. LSAF Test Cell – End View (not to scale).

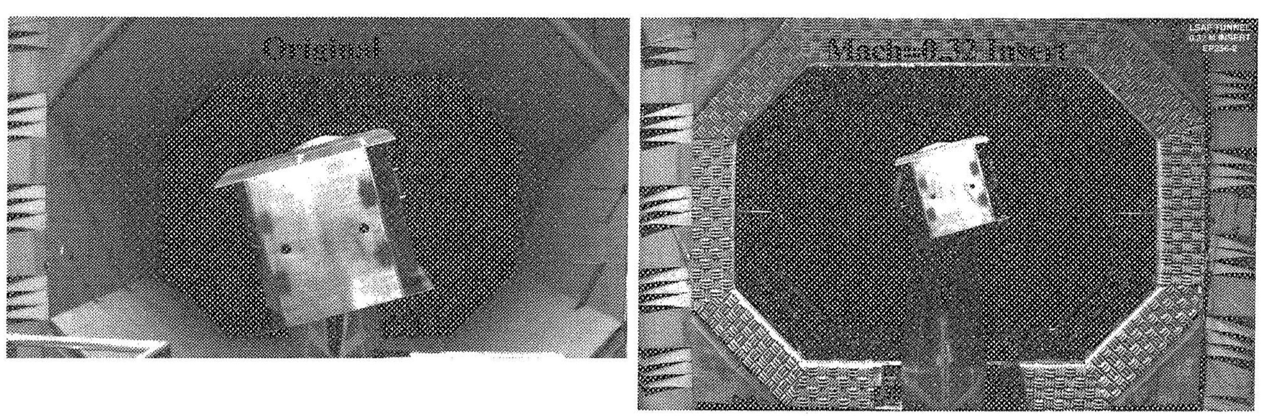


Figure 1.4. Windtunnel Insert, Original vs with Mach0.32 Insert

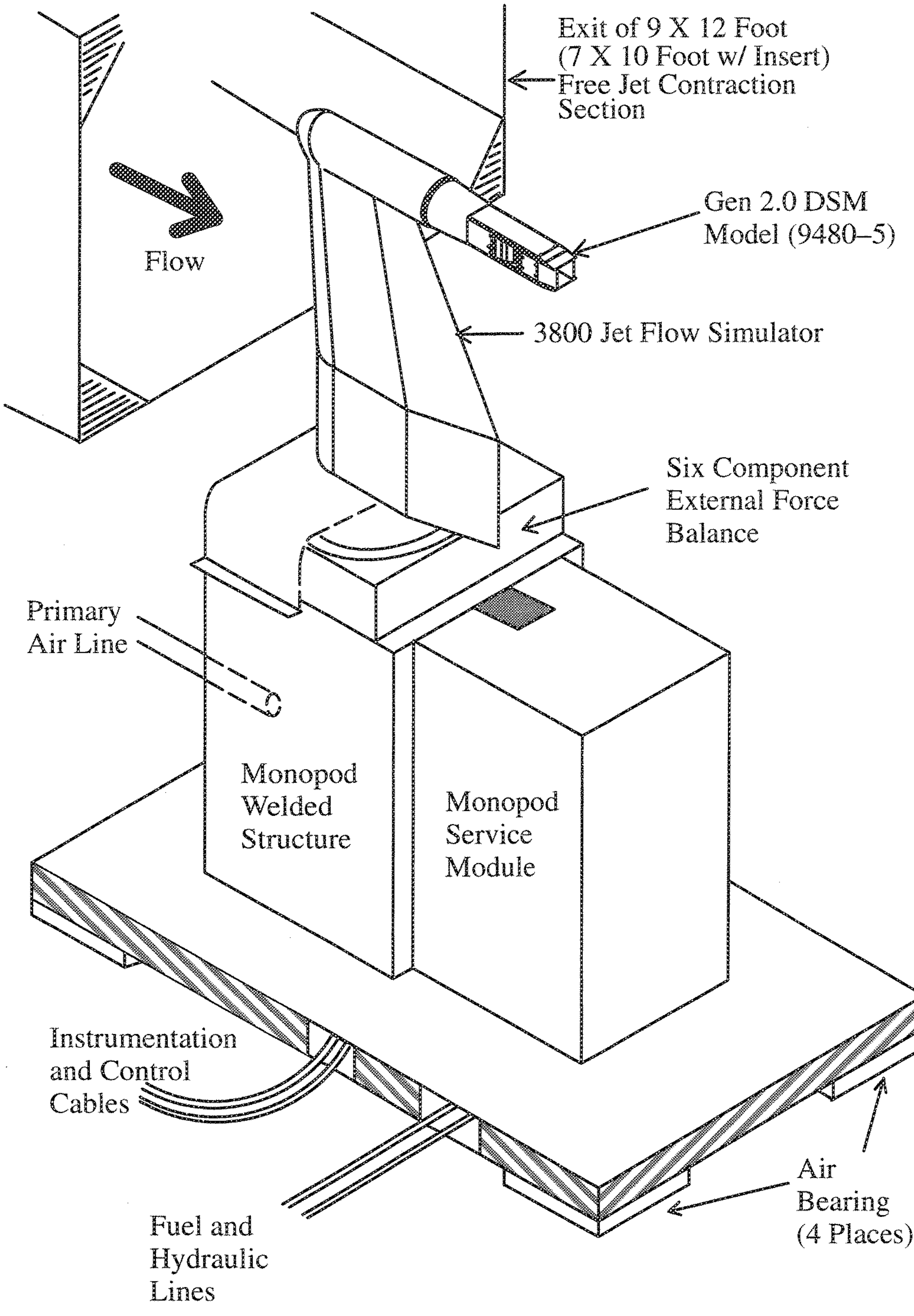


Figure 1.5. LSAF Monopod (not to scale).

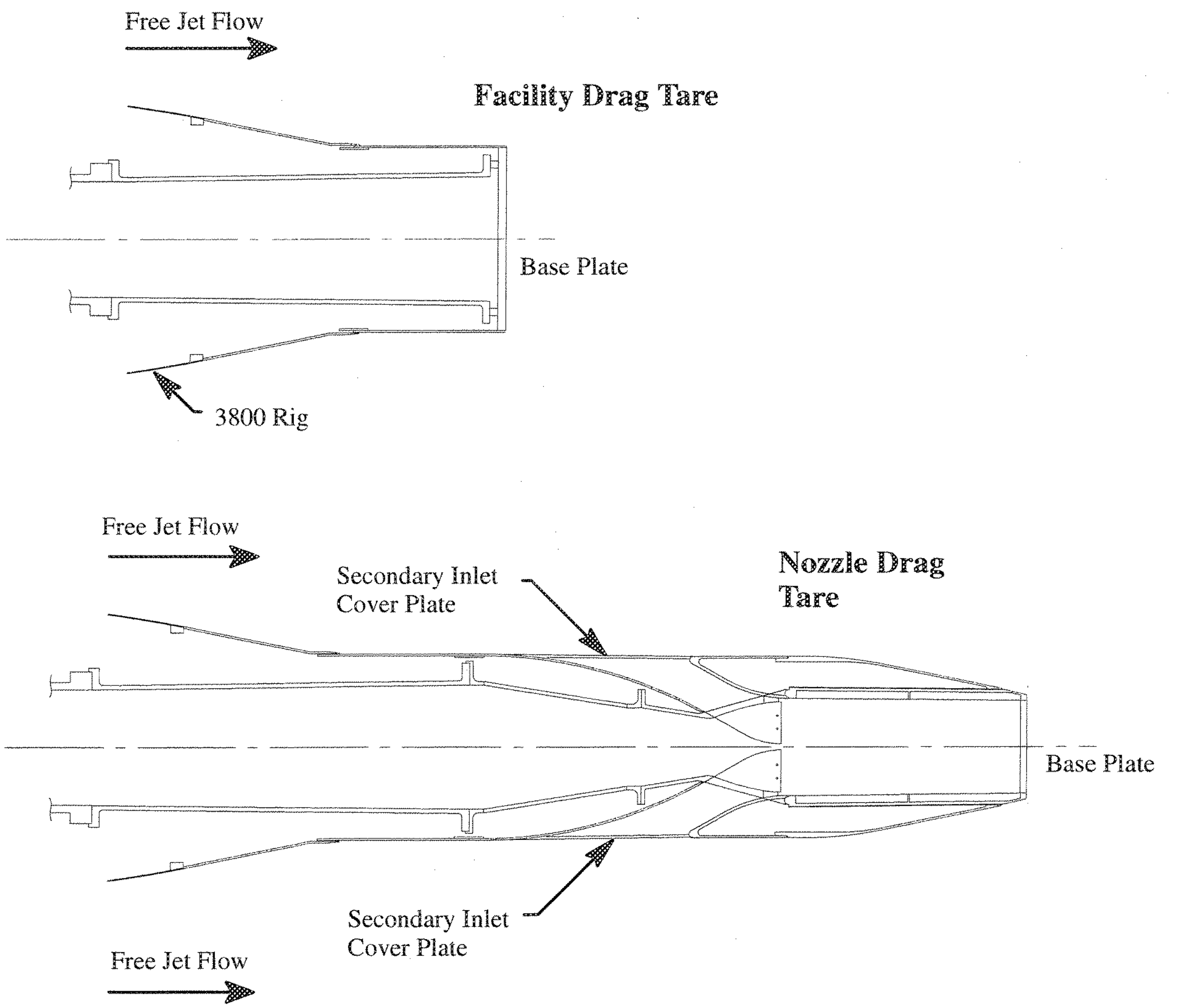


Figure 1.6. Drag Tare Hardware.

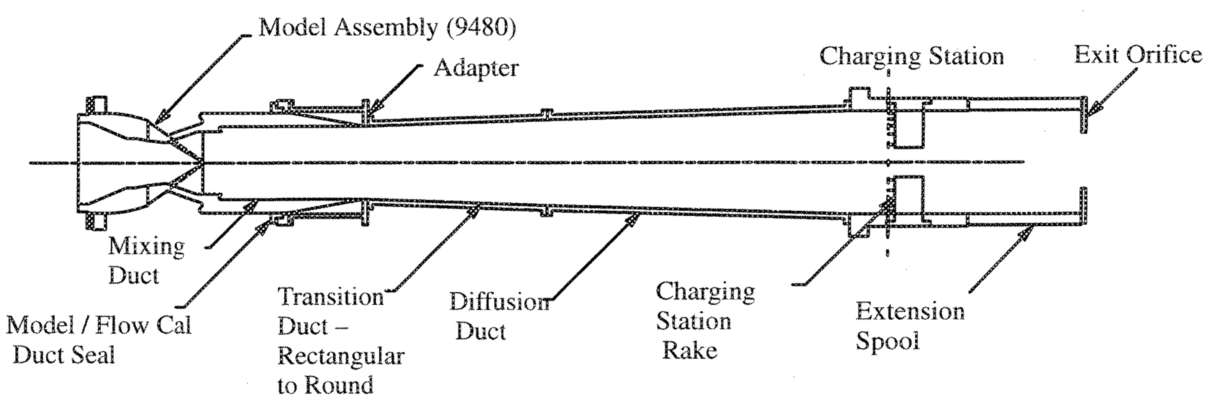


Figure 1.7. Flow Calibration Duct.

Probe	Type of Measurement	Notes/Comments
Kiel Probe	Total Pressure, Total Temperature	Static Pressure assumed to be ambient. Temperature measurement offset by .38 inch.
Pitot Static Probe	Total Pressure, Static Pressure, Total Temperature	Static pressure measurement down stream of the Total pressure measurements.
Pratt and Whitney's 5 Hole Probe	Pressure ratio calibrated to measure Mach Number	No temperature measurement, required second runs with different probe for velocity calculation.
Pratt Whitney's 5 Hole Probe w/ Stag. Temp.	Pressure ratio calibrated to measure Mach Number and Total Temperature	Able to calculate velocity and accurate static pressure with the same run. Temperature measurement offset by 0.55 inch.

Table 1.1. Types of Exit Rake Probes

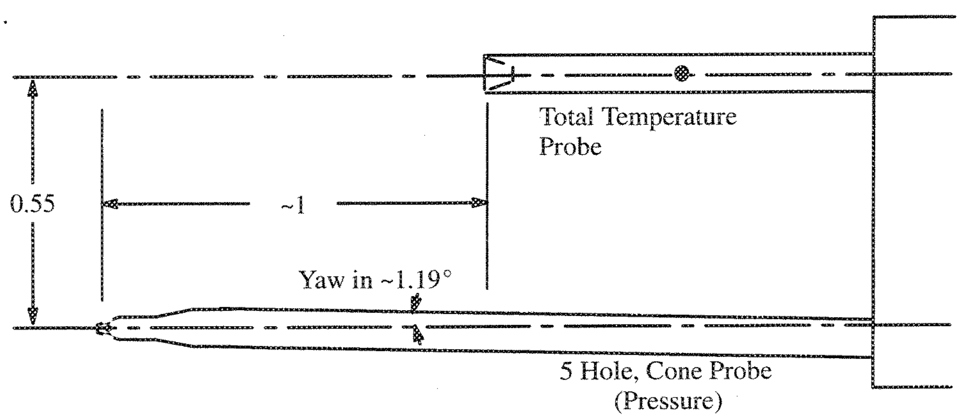


Figure 1.8. Exit Survey Probe, 5 Hole with Thermocouple.

2.0 Model Hardware

The Gen 2.0 LSAF test program used 2 basic mixer/ejector models, the DSM (Down Stream Mixer) provided by Pratt Whitney, and the HAM (Hot Acoustic Mixer) provided by General Electric. Table 2.1 provides a list of all the GEN2 mixers tested in each at LSAF. The table also provides information about some key mixer parameters such as SAR (suppressor area ratio), ASAR (aerodynamic suppressor area ratio), model scale, and penetration (the relative height of the mixer lobes to the height of the ejector). Table 2.2 provides some general information about the DSM and HAM models, such as mixing duct length (L_{eject}), treated area, and treated area ratio (A_{treat}/A_{mix}). Figure 2.1 shows the DSM model installed on the 3800 Jet Flow Simulator in the LSAF and Figure 2.2 shows the HAM model. The models were installed such that the ejector inlets are rotated 15° off of horizontal. This orientation is rotated 75° from the current production aircraft/nozzle installation. The model's orientation was made to facilitate the required acoustic measurements.

Figure 2.3 illustrates the basic components of the mixer/ejector models. The mixers are designed with 20 secondary lobes and 18 primary lobes. Full width secondary lobes were next to the sidewalls. Two pins are located in each secondary passage of the lobes to add structural strength.

For the DSM, two types of mixers were tested, vortical (rotating chute) and axial (best aero). The vortical were designed with severe rotating chute constraints. These constraints included squared chute lobes for blending with the divergent flap during non–suppressed (stowed) mode operation, straight chute sidewalls for sealing during stowed mode, and straight chute flow path (vortical) again for blending with the divergent flap during stowed mode An attempt was made to incorporate some turning during suppressed mode on the primary chutes through the flapper valves. The flapper valves allowed some variation in penetration for the vortical mixers. These penetrations are noted in Table 2.1. The best aero chutes were designed for fixed mixer which allowed more freedom for aerodynamic shaping. These changes included shaped/contoured sidewalls, turning on the primary and secondary sides of the chute lobes for axial flow, and shaped lobes. Figure 2.4 illustrate some of the differences between these two types of DSM mixers.

The HAM model ejector was very similar to the DSM, but for these key exceptions: ejector exit aspect ratio (HAM aspect ratio=1.5, DSM aspect ratio=1.17), secondary inlet contours (HAM had a longer and shallower secondary inlet ramp and lip), and primary nozzle contours (HAM had shallower turning angles in the chute lobes). The design of the secondary inlet in the DSM reflected the full scale HSR baseline at the time (Jan. 95). The HAM secondary inlets, however, more closely represent the current full scale HSR baseline (July 96). The shallower turning angles in the HAM mixers are a consequence of higher ejector aspect ratio.

Similar to the DSM, two types of HAM mixers were tested, vortical (NRA) and axial (best aero). The earlier NRA mixer was not designed to the same constraints as the DSM rotating chute mixer. But it has square lobes in keeping with a common vortical mixing design philosophy. Figure 2.5 compares the HAM NRA and Best Aero mixers.

The HAM Best Aero mixers were tested with two different mixing duct lengths, short (full scale≈120" flap), and long (full scale≈160" flap). The duct extension was achieved by adding a hardwall extension to the short duct just downstream of the mixer exit. The short and long duct are compared in Figure 2.6. The boattail angle of the long duct fairing is shallower than that of the short duct. In the treated configuration, the two duct lengths have the same amount of acoustic treatment.

Five types of acoustic treatment were tested. They are silicon carbide (SiC) foam, nickel based foam metal, "large cell" single degree of freedom with square cells, and honeycomb cell single

degree of freedom treatment with felt metal facesheet. The silicon carbide and foam metal bulk absorbers were made in two thicknesses – 13 mm and 7 mm. The bulk absorbers and the "large cell" treatment used trays with perforated sheet on the flow surface. The perf sheet is integral to the acoustic trays which housed the various bulk liners. The 0.025" thick perforated face sheet of the acoustic treatment trays had 37% open area with 0.045" hole diameter. The standard Sic bulk absorber for the 13 mm treatment had 100 pores/inch and was 0.485" thick. Two different hardwall treatments were tested in the HAM model. The standard hardwall used smooth trays instead perf plate. The "simulated" hardwall used the perf plate trays with foam metal blocked by 2mil thick sheet metal.

A chevron configuration was tested with HAM mixers 4 and 8 (see Table 2.1). The chevron configuration is basically a mixing duct extension where the nozzle exit edges are scarfed into triangular shapes. The chevron configuration is illustrated in Figure 2.7. Only one chevron configuration was tested at LSAF, however, several configurations were tested at GE's Cell 41 and these results were used to limit the amount of testing at LSAF.

Additional information about the DSM model is given in Reference 2.0, DSM Test Plan, and about the HAM model in Reference 3.0, HAM Test Plan. Some of the information provided in the references regarding mixer geometry was incomplete or has changed. This information is updated in Appendix A of this document.

DSM Mixers, Amix=58 in^2							
Mixer	Type	SAR	ASAR	A8	Model Scale *	Penetration PEN	Description
1	Rotating	3.38	3.47	17.160	0.11489	0.85, 1.00	SAR Variation
2	Rotating	2.5	2.49	23.200	0.13359	0.85, 0.925, 1.00	Baseline – Rotating
4	Best Aero	2.5	2.67	23.200	0.13359	1.00	Pen Variation – Best Aero
5	Best Aero	2.5	2.52	23.200	0.13359	0.925	Baseline Best Aero
6	Best Aero	2.5	2.50	23.200	0.13359	0.85	Pen Variation – Best Aero
8	Best Aero	2.2	2.34	26.364	0.14241	0.925	SAR Variation – Best Aero
9	Best Aero	2.9	2.89	20.00	0.12403	0.925	SAR Variation – Best Aero
HAM Mixers, Amix=64.7 in^2							
Mixer	Type	SAR	ASAR	A8	Model Scale *	PEN	Description
3	Best Aero	2.5	2.59	25.880	0.14110	1.00	Pen Variation – Best Aero
4	Best Aero	2.5	2.62	25.880	0.14110	0.925	Baseline Best Aero
10	Best Aero	2.5	2.63	25.880	0.14110	0.85	Pen Variation – Best Aero
8	Best Aero	2.9	3.06	22.310	0.13100	0.925	SAR Variation – Best Aero
21	NRA	2.8	2.88	23.107	0.13332	1.00	Vortical Flow Style Mixer
* Note: Reference 4, Full Scale Nozzle, A8=1300, Cycle=3770							

Table 2.1. GEN2 Mixers Tested in LSAF

Model	L_{eject} (in)	Treated Area (in^2)	$A_{treated}/A_{mix}$
DSM Rotating	16.119	295.850	5.101
DSM Best Aero	15.978	295.850	5.101
HAM	16.586	415.359	6.42
HAM + Extension	21.681	414.314	6.40

Table 2.2. GEN2 Model Ejector Length and Treated Area.

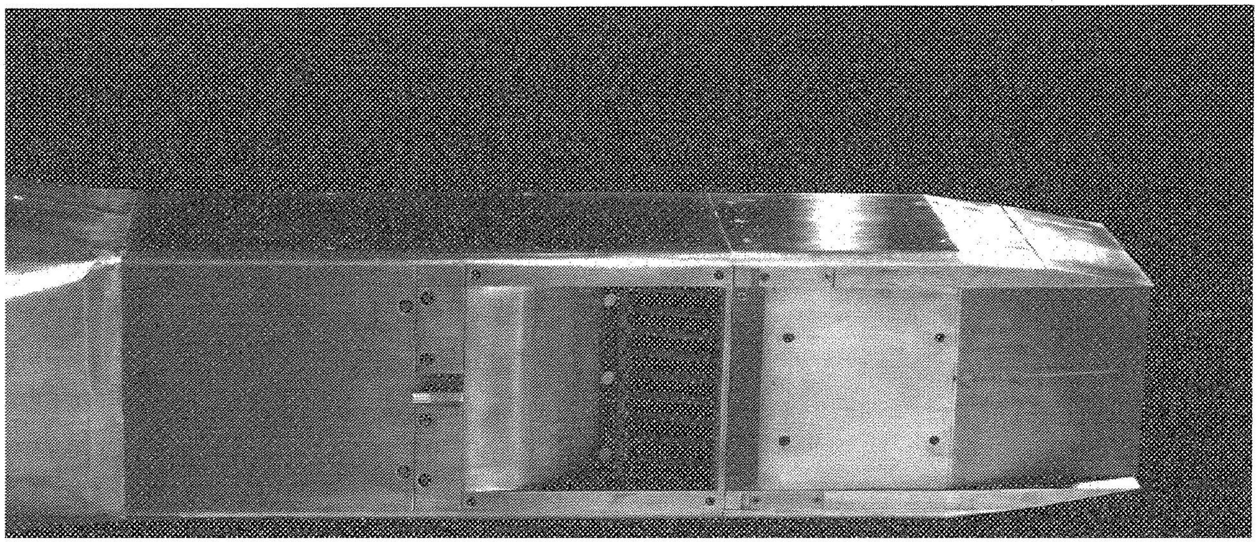


Figure 2.1, Gen 2.0 DSM Model Installed in LSAF (Side View)

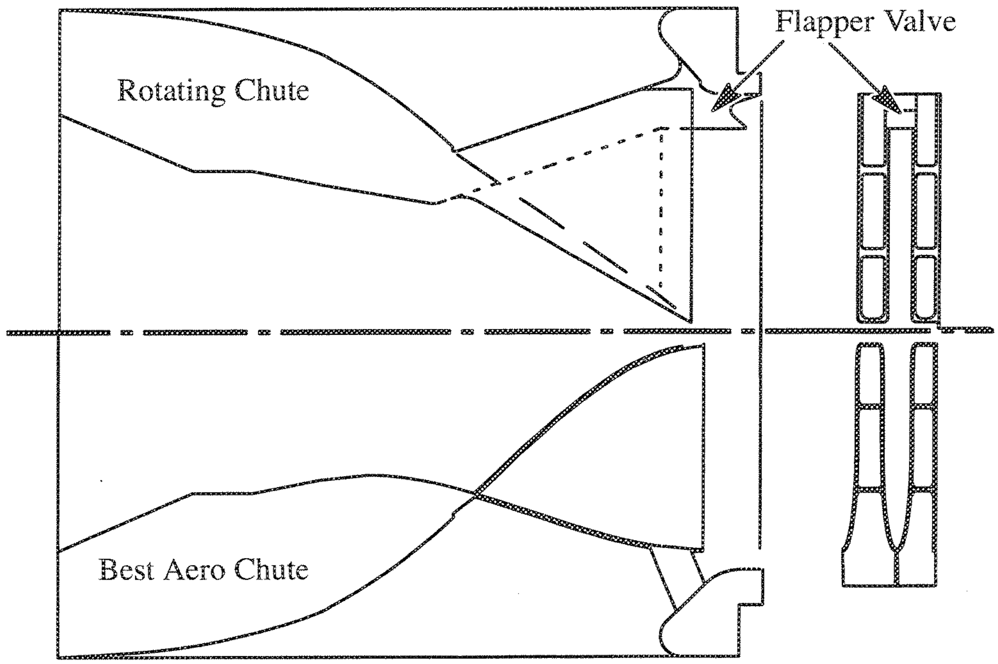


Figure 2.4 Comparison Between DSM Rotating and Best Aero Chutes

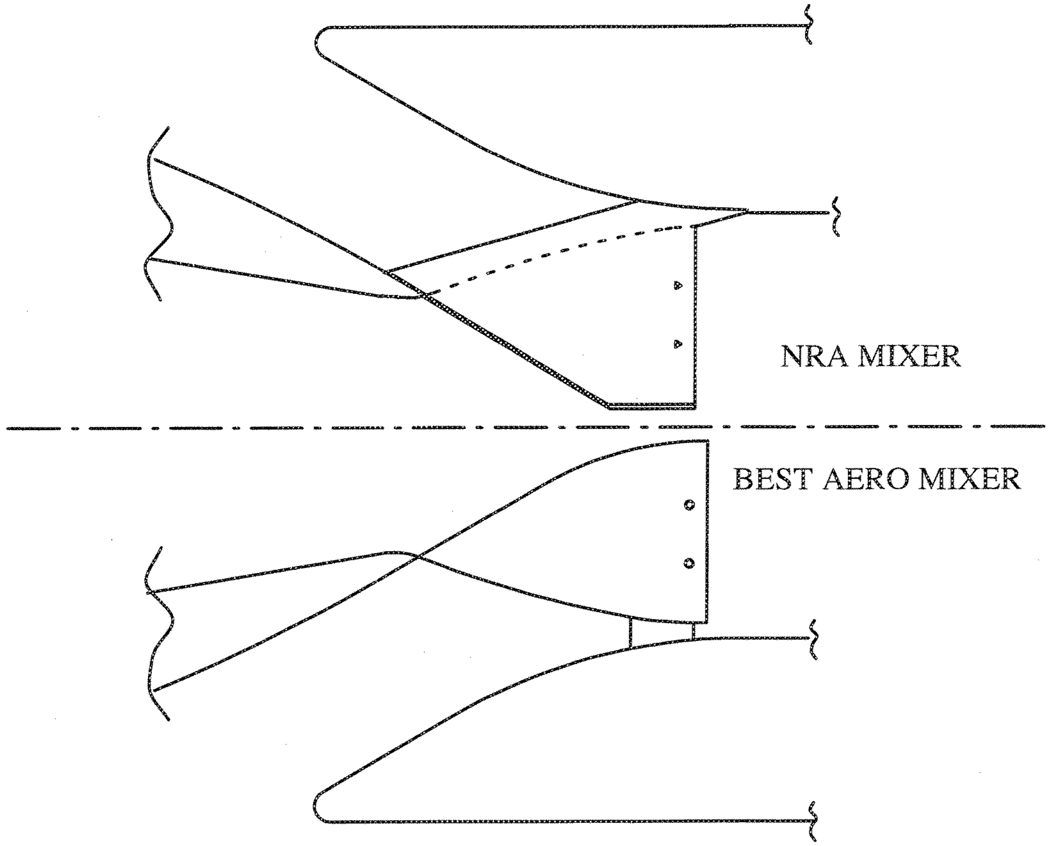


Figure 2.5, Comparison Between HAM NRA and Best Aero Mixer/Ejectors

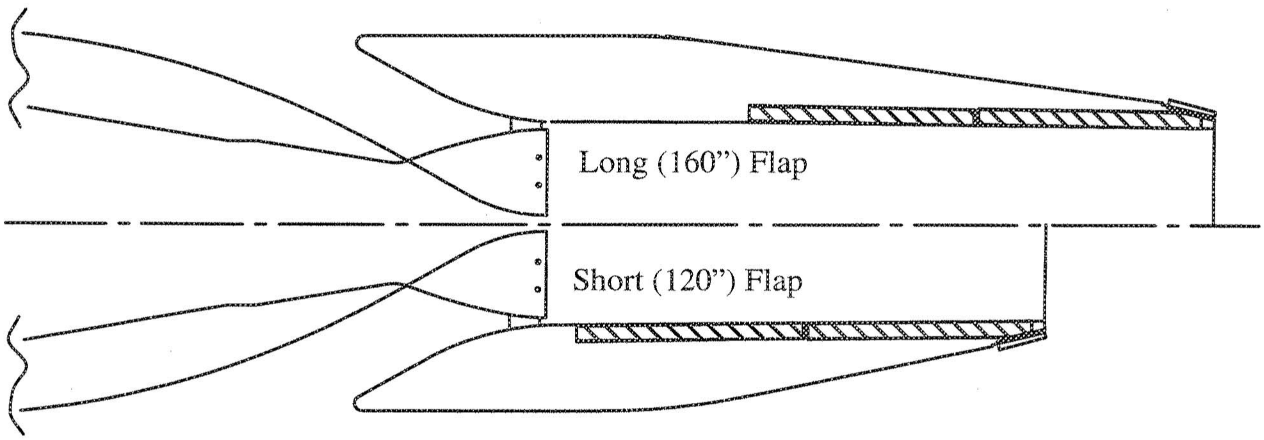


Figure 2.6, Comparison Between HAM Long (160") and Short (120") Flaps

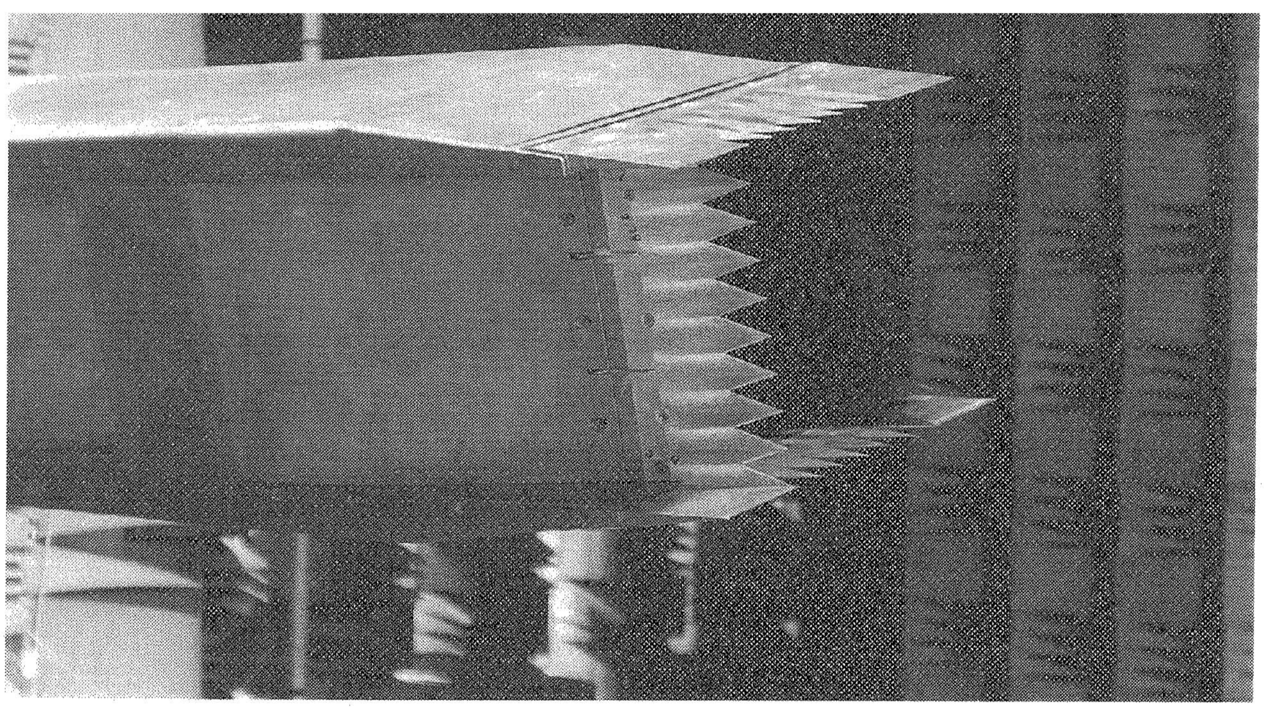


Figure 2.7, Gen 2.0 HAM Model With Chevrons Installed

3.0 Data Acquisition and Processing

3.1 Aerothermal Data Acquisition and Processing

Aerothermal data reduction was done using the LSAFAT computer program written by the Noise Engineering Laboratory staff. This section contains the definitions of the parameters used in that computer program.

3.1.1 Aerothermal Data Acquisition and Processing Applicable For Both DSM and HAM

The primary pressure ratio, *NPR*, is defined as:

$$NPR = \frac{P_{tpa}}{P_{st}}$$

where P_{tpa} is the arithmetic (or area−weighted) average of the 18 total pressure probes at the primary charging station, and

P_{st} is the free jet static pressure

The primary or charging station distortion (max – min) is calculated from:

$$P_{tpdst} = \frac{Pt_{\max} - Pt_{\min}}{P_{tpa}}, \quad total\ pressure\ distortion$$

$$T_{tpdst} = \frac{Tt_{\max} - Tt_{\min}}{T_{tpa}}, \quad total\ temperature\ distortion$$

The discharge coefficient, *Cdp*, is defined as:

$$Cdp = \frac{w_{pt}}{w_{ip}}$$

where w_{pt} is the measured primary airflow, and

w_{ip} is the ideal primary airflow calculated as follows:

$$w_{ip} = P_{tpa} A_{reapinh} M_p Z \sqrt{\frac{\gamma_p g}{R_p T_{tpa}}} \left[1 + \frac{(\gamma_p - 1)}{2} M_p^2 \right]^{-\frac{(\gamma_p + 1)}{2(\gamma_p - 1)}}$$

where P_{tpa} is defined in equation above,
T_{tpa} is the arithmetic (or area−weighted) average of the 15 total temperature probes at the primary charging station,
$A_{reapinh}$ is the hot primary throat area,
R_p is the gas constant for primary flow, (ft−lbf)/(lbm−R),
γ_p is the ratio of specific heats,
Z is a compressibility factor (LSAF supplied subroutine)
M_p is the primary throat Mach number defined as:

$$M_p = \sqrt{\left[\left(\frac{P_{tpa}}{P_{st}} \right)^{\frac{(\gamma_p - 1)}{\gamma_p}} - 1 \right] \left(\frac{2}{\gamma_p - 1} \right)} \qquad for \quad \frac{P_{tpa}}{P_{st}} < \left[1 + \frac{(\gamma_p - 1)}{2} \right]^{\frac{\gamma_p}{\gamma_p - 1}}, \quad or$$

$$M_p = 1.0 \qquad for \quad \frac{P_{tpa}}{P_{st}} \geq \left[1 + \frac{(\gamma_p - 1)}{2} \right]^{\frac{\gamma_p}{\gamma_p - 1}}$$

The thrust coefficients, *Cfnmix, Cfnmab, Cfgmix, and Cfgmab*, is defined as:

$$Cfnmix = \frac{Fnmix}{Fip}, Fnmix = Net\ Thrust,\ No\ Aftbody\ Drag = -Af + Drn$$

$$Cfnmab = \frac{Fnmab}{Fip}, Fnmab = Net\ Thrust,\ With\ Aftbody\ Drag = -Af + Dr$$

$$Cfgmix = \frac{Fgmix}{Fip}, Fgmix = Fnmix + Dram$$

$$Cfgmab = \frac{Fgmab}{Fip}, Fgmab = Fnmab + Dram$$

where
- Af is the measured axial thrust generated by the nozzle, corrected for balance tares
- Drn is the Nozzle Drag Tare (nozzle exit)
- Dr is the Facility Drag Tare (nozzle / facility interface)
- Dram Secondary Inlet Ram Drag
- Fip Ideal Primary Thrust

$$Dram = \frac{W_s V_t}{32.174}, \ Secondary\ Inlet\ Ram\ Drag$$

$$Fip = \frac{W_{pt} V_{ip}}{32.174}, Ideal\ Primary\ Thrust$$

$$V_{ip} = \sqrt{\left(2 g_p R_p T_{tpa}\right)\left(\frac{\gamma_p}{\gamma_p - 1}\right)\left[1 - \frac{P_{tpa}}{P_{s\infty}}^{-\left(\frac{\gamma_p - 1}{\gamma_p}\right)}\right]}, Ideal\ Primary\ Velocity,\ Fully\ Expanded\ to\ Freestream$$

The aspiration, or mass flow ratio, is defined as:

$$MFR = \frac{w_s}{w_{pt}} \qquad \text{where, } w_s = Measured\ Secondary\ Airflow$$

The corrected aspiration is defined as

$$MFRC = MFR\sqrt{\frac{T_{t_{fj}}}{T_{tpa}}}$$

The secondary and primary airflows are corrected to standard day

$$w_{ptc} = w_{pt}\frac{\sqrt{\frac{T_{tpa}}{518.7}}}{\frac{P_{tpa}}{14.7}} \qquad w_{sc} = w_s\frac{\sqrt{\frac{T_{tfj}}{518.7}}}{\frac{P_{tt}}{14.7}}$$

The primary choked flow area, suppressor area ratio, and choked suppressor area ratio are calculated from:

$$SAR = \frac{A_{mix}}{A_{pri}}, A_{mix} = 58.0 in^2 DSM, 64 in^2 HAM$$

$$ASAR = \frac{A_{mix}}{A_{chk}} \qquad A_{chk} = \frac{w_{pt}\sqrt{T_{tpa}}}{wtap_{chk} P_{tpa}} \qquad wtap_{chk} = \frac{\sqrt{\frac{g\gamma_p}{R_p}}}{\left(1 + \frac{\gamma_p - 1}{2}\right)^{\frac{\gamma_p + 1}{2\gamma_p - 1}}}$$

The mixed flow parameters are calculated as follows:

$$P_{t_m} = P_s \left(1 - \frac{V_m^2}{\left(2 g_c R_m \frac{\gamma_m}{\gamma_m - 1} Tt_m \right)} \right)^{-\frac{\gamma_m}{\gamma_m - 1}}$$

$$T_{t_m} = \frac{W_{pt} c_{pp} Tt_p + W_s c_{ps} Tt_s}{c_{pm} W_m}$$

$$c_{pp} = \gamma_p \frac{R_p}{\gamma_p - 1} \quad , \qquad c_{ps} = \gamma_s \frac{R_s}{\gamma_s - 1}$$

$$c_{pm} = \frac{W_{pt} c_{pp} + W_s c_{ps}}{W_m}$$

$\gamma_m, R_m,$ *Calculated Using LSAF Tables*

$$Vi_m = \frac{W_{pt} Vi_p + W_s Vi_s}{W_m}$$

$$V_m = \frac{F_{gmix} g_c}{w_m}$$

$$w_{mixed} = w_s + w_{pt}$$

3.1.2 Aerothermal Data Acquisition and Processing Unique to the DSM

The secondary flow rate for the DSM was calculated from a flow tube calibration. The total flow through the flow tube was calculted by:

$$w_{tot} = \sum_{i=1}^{i=40} Pt_i \, A_i \sqrt{\frac{2g}{R_t \, T_{tfta}}\left(\frac{\gamma_t}{\gamma_t - 1}\right)\left[\frac{Pt_i}{Ps_j}^{\frac{-2}{\gamma_t}} - \frac{Pt_i}{Ps_j}^{-\left(\frac{\gamma_t+1}{\gamma_t}\right)}\right]}$$

$Pt_i =$ *Individual Total Pressure on Calibration Tube Rake*

$A_i =$ *Incremental Area Associated with Each Pt* $= \dfrac{A_{flow\ tube}}{40}$

$Ps_i =$ *Static Pressure Assigned to* Pt_i

$$Ps_i = P_{sftra} + \left(Ps_j - P_{sftra}\right)\frac{r_{rake}}{r_{probe}}$$

$P_{sftra} =$ *Numerical Average of 8 Static Taps at Flow Tube Rake*

$Ps_j =$ *Static Tap Closest To Rake Arm Total Pressure,* Pt_i *is located on*

$r_{rake} =$ *radius of flow tube at rake location*

$r_{probe} =$ *radius at* Pt_i *from center of flow tube*

$T_{tfta} =$ *Numerical Average of 16 Total Temperatures at Flow Tube Rake*

γ_t *and* $R_t =$ *Gas Constants for Mixed Total Airflow*

The secondary airflow through the flow tube is then calculated :

$$w_s = w_{tot} - w_{pt}$$

To compare against and as a backup for when the flow tube calibration cannot be done, secondary airflow will be calculated by:

$$w_{s2} = \sum_{i=1}^{6} P_{tmx_i} \, A_i \sqrt{\frac{2g}{R \, T_{t\infty}}\left(\frac{\gamma}{\gamma - 1}\right)\left[\frac{P_{tmx_i}}{Ps_i}^{\frac{-2}{\gamma}} - \frac{P_{tmx_i}}{Ps_i}^{-\left(\frac{\gamma+1}{\gamma}\right)}\right]}$$

$P_{tmx_i} =$ *Individual Total Pressure on Mixer Lobes, PTMXA01 – PTMXA06*

$A_i =$ *Incremental Area Assigned For Each Mixer Total Pressure, To Be Provided For each Mixer.*

$Ps_i =$ *Static Pressure Assigned to Each Total Pressure. Use a Linear Variation From PSMXA02 to PSMXA17/A19*

3.1.3 Aerothermal Data Acquisition and Processing Unique to the HAM

For the HAM nozzle the secondary flow rate is calculated using the existing inlet total pressure rakes. The flow rate in the upper inlet is calcualated using rakes PTRB and PTRE as follows:

$$w_{su} = \sum_{j=1}^{i=2} \sum_{i=1}^{i=8} Ptu_{i,i}\, Au_{i,j} \sqrt{\frac{2g}{R_s\, T_t}\left(\frac{\gamma_t}{\gamma_t - 1}\right)\left[\frac{Ptu_{i,i}}{Psu_{i,j}}^{\frac{-2}{\gamma_t}} - \frac{Ptu_{i,i}}{Psu_{i,j}}^{-\left(\frac{\gamma_t+1}{\gamma_t}\right)}\right]}$$

$$Ptu_{i,j} = \begin{matrix} For\ j\ = 1,\ Ptu_{i,i} = PTRB(i),\ i\ = 1,8 \\ For\ j\ = 2,\ Ptu_{i,j} = PTRE(i),\ i\ = 1,8 \end{matrix}$$

$$Au_{i,j} = Incrimental\ Area\ Associated\ with\ Each\ Pt\ = \frac{26.6528}{16} = 1.6658 in^2$$

$$Psu_{i,j} = Static\ Pressure\ Assigned\ to\ Ptu_{i,j}$$

$$Psu_{i,j} = \begin{matrix} For\ j\ = 1,\ Psu_{i,i} = PSRB(1)\ +\ \frac{i}{9}[PSRB(2) - PSRB(1)] \\ For\ j\ = 2,\ Psu_{i,i} = PSRE(1)\ +\ \frac{i}{9}[PSRE(2)-PSRE(1)] \end{matrix}$$

$$T_t = Tunnel\ Total\ Temperature,\ R$$

$$\gamma_t\, and\, R_t,\ Gas\ Constants\ for\ Tunnel\ Air,\ 1.4\ and\ 53.35$$

The flow rate in the lower inlet is calcualated using rake PTRK as follows:

$$w_{sl} = \sum_{i=1}^{i=8} Ptl_i\, Al_i \sqrt{\frac{2g}{R_s\, T_t}\left(\frac{\gamma_t}{\gamma_t - 1}\right)\left[\frac{Ptl_i}{Psl_i}^{\frac{-2}{\gamma_t}} - \frac{Ptl_i}{Psl_i}^{-\left(\frac{\gamma_t+1}{\gamma_t}\right)}\right]}$$

$$Ptl_i = Ptl_i = PTRK(i),\ i\ = 1,8$$

$$Al_i = Incrimental\ Area\ Associated\ with\ Each\ Pt\ = \frac{26.6528}{8} = 3.3316\ in^2$$

$$Psu_{i,j} = Static\ Pressure\ Assigned\ to\ Ptu_{i,j}$$

$$Psu_i = Psl_i = PSRK(1)\ +\ \frac{i}{9}[PSRK(2)-PSRK(1)]$$

$$T_t = Tunnel\ Total\ Temperature,\ R$$

$$\gamma_t\, and\, R_t,\ Gas\ Constants\ for\ Tunnel\ Air,\ 1.4\ and\ 53.35$$

The total secondary flow rate is calculated:

$$w_s = w_{su} + w_{sl}$$

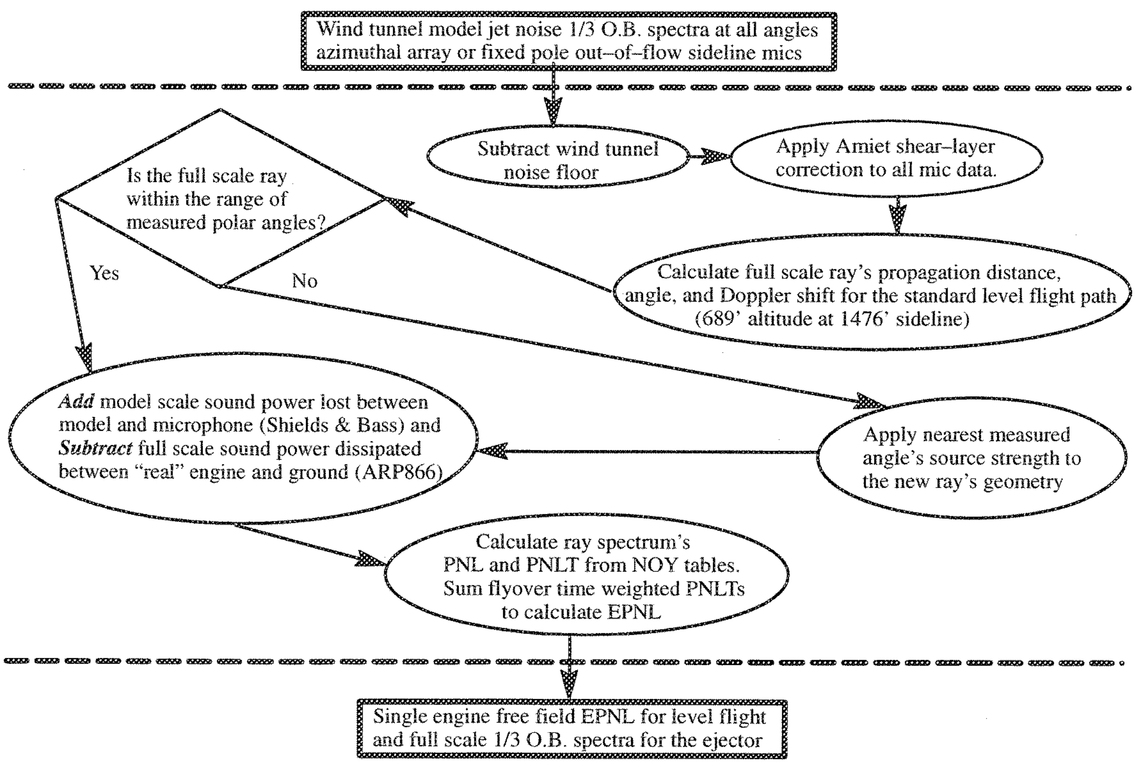
3.2 Acoustic Data Acquisition and Processing

Microphone data was analyzed in third octave bands and 800 narrowbands from 200Hz to 80 KHz by two B&K2133 analyzers (third octave) and an HP3562A analyzer (narrow) simultaneously. The ADP–1 acoustic data processor on the Prime computer merged the acoustic and aerothermal data to create an as–measured RDS (Boeing Readable Data Standard) format file for each condition. The as–measured acoustic files include corrections for barometric pressure, microphone sensitivity (–6 dBVrms, +/–0.1 dBV), calibrator level (124 dB), and line, free field, and pressure response.

To get full scale flight EPNL from model scale acoustic data requires the use of a flight extrapolation procedure (see flow chart below). The extrapolation program corrects for scale factor based on the primary nozzle exit area. Amiet's method is used to correct for the wind tunnel free jet shear layer. ARP866 atmospheric absorption (lower band edge absorbtion above 4KHz) is used to correct the noise to FAR 36 standard day (77 deg. F, 70% RH). To correct for absorbtion of sound between the model and the 15' microphone array, the Shields and Bass absorbtion method at model scale frequencies is used. The extrapolations are for a single engine with no jet shielding, ground reflection or ground absorbtion. The full scale flight path used is the agreed upon 689' altitude level flyover at the 25 degree azimuthal position (1476' sideline). This results in a 1629' minimum distance from the observer point which is used for all azimuthal angles measured.

The aerothermal data (at), as–measured acoustic (sac), and full scale extrapolated (ext) files were ported to the lab's HP/Apollo ring, checked for format errors, and DES encrypted for transmission to vendors and NASA via the Internet.

Procedure for Extrapolation of LSAF Gen 2.0 Noise Data to Flyover Conditions



4.0 Test Conditions / Schedule / Configuration

4.1 Test Conditions

Test conditions varied some through the length of the test. Table 4.1 gives the basic throttle line used during the GEN2 test. The 3765 throttle line was used through all the test, but the 3570.80 cycle conditions were added about midway into testing. Before the tunnel Mach 0.32 insert was installed, testing was limited to Mach=0.245. DSM mixers 1, 2, and 8 were all tested prior to the tunnel insert installation. For those mixers the primary Mach numbers tested were 0.0, and 0.245 with an occasional excursion to Mach=0.12. After the insert the primary Mach numbers tested for the DSM were 0.0, 0.245 and 0.32. The Mach numbers tested during the HAM testing were primarily limited to 0.0 and 0.32. The decision to limit the testing was due to time constrants.

Test Throttle Line			
Point	NPR	T8 °R	Comments
1	1.51	970	PC 26, 20% Fn–3765
2	1.99	1139	PC 32, 40% Fn–3765
3	2.37	1238	Cutback – PC 38, 60% Fn=3570.80
4	2.48	1291	Cutback – PC 38, 60% Fn=3765
5	2.96	1416	PC 44, 80% Fn–3765
6	3.25	1482	Sideline – PC 50, 100% Fn–3570.80
7	3.43	1551	Sideline – PC 50, 100% Max Dry Fn–3565
8	4.0	1700	3765

Table 4.1. GEN2 Test Throttle Line

4.2 Test Schedule

Figure 4.1 provides the time flow for when the various hardware was tested. The GEN2 test was originally planned to end December 1995. However, delays in hardware delivery and the addition of HAM model testing, not originally planned, extended the length of the test program. Testing over 13 months from June 1995 through July 1996 prevailed over heat wave, wind storm, flood, machinists strike, ice storm, earthquake, near catastrophic fuel leak, and demolition of a nearby building.

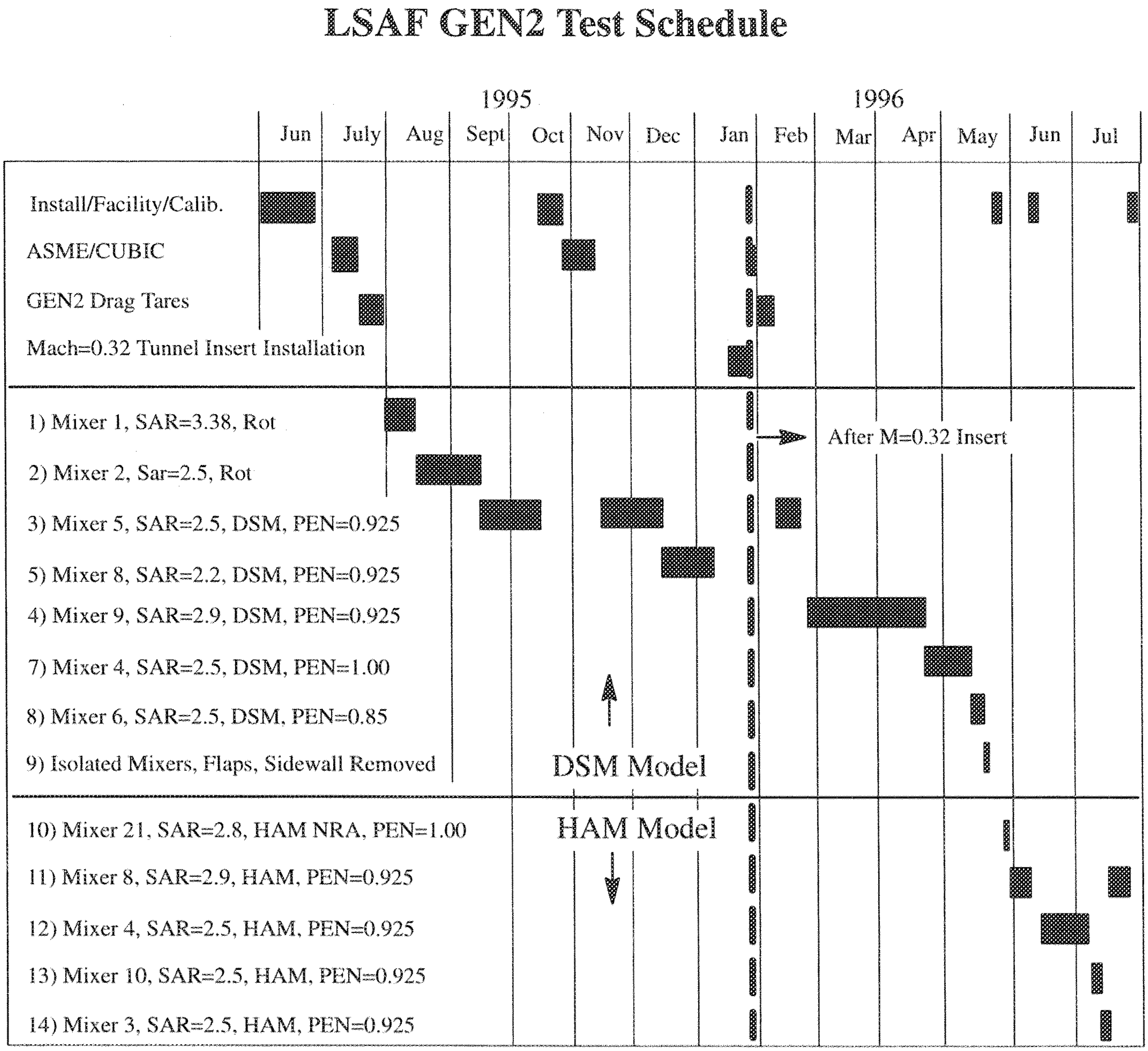


Figure 4.1. GEN2 Test Schedule

4.3 Test Configurations

The Configurations tested at LSAF are given in Table 4.2. The table shows the various parametrics that were examined with each of the mixers. Tables 4.3 and 4.4 list the configurations tested for the DSM and HAM models. Figures 4.2 and 4.3 provide the key to interpreting the configuration numbering used in the test. A log of the information acquired at each configuration is provided in Appendix B.

DSM Model Parametrics

Mixers	Liners						MAR				PEN			Flow Tube	Inlet Lip	Isolated Mixer	Mixer Exit Rake	Nozzle Exit Rake
	Hardwall	13mm SiC (Porous)	7mm SiC (Porous)	7mm SDOF (Felt)	13mm SDOF (Porous)	13mm Foam Metal	0.85	0.90	0.95	1.00	0.85	0.925	1.00					
1	X	X							X		X		X			X	X	
2	X	X	X				X	X	X	X	X	X	X	X		X	X	
4	X	X						X	X				X			X		X
5	X	X	X	X		X	X	X	X	X		X		X		X	X	X
6	X	X						X	X		X			X		X		X
8	X	X						X	X			X		X		X		
9	X	X	X	X	X			X	X	X		X		X	X	X		X

HAM Model Parametrics

Mixers	Liners				MAR		PEN			Flap Length		Chevron #7	Mixer Exit Rake	Nozzle Exit Rake
	Hardwall	13mm SiC (Porous)	13mm Foam Metal	Hardwall Porous	0.90	0.95	0.85	0.925	1.00	120" (Full Scale)	160" (Full Scale)			
3	X	X				X			X	X				
4	X	X			X	X		X		X	X	X	X	X
8	X	X		X		X		X		X	X	X	X	X
10	X	X				X	X			X				
21	X		X			X			X	X				

Table 4.2, Model Parametrics

DSM MIXERS								
Configuration	Mixer	Style	SAR	PEN	Length	MAR	Liner	Other
000.020	–	–	–	–	–	–	–	Strut Drag Tare
054.031	–	–	–	–	Long	0.85	–	Nozzle Drag Tare
052.031	–	–	–	–	Long	0.95	–	Nozzle Drag Tare
000.520	–	–	–	–	–	–	–	Strut Tare, M=.32 Insert
052.532	–	–	–	–	Long	0.95	–	Nozzle Tare, M=.32 Insert
100.300	1	Rot	3.38	–	–	–	–	Isolated Mixer
100.506	1	Rot	3.38	–	–	–	–	Isolated Mixer
152.101	1	Rot	3.38	1.00	Long	0.95	HW	
152.301	1	Rot	3.38	0.85	Long	0.95	HW	
152.303	1	Rot	3.38	0.85	Long	0.95	HW	Mixer Exit Rakes
1152.100	1	Rot	3.38	1.00	Long	0.95	HW	Nozzle Rotated 15°
172.101	1	Rot	3.38	1.00	Long	0.95	13mm Sic	
172.301	1	Rot	3.38	0.85	Long	0.95	13mm Sic	
251.240	2	Rot	2.5	0.925	Long	1.00	HW	Flow Tube
200.200	2	Rot	2.5	–	–	–	–	Isolated Mixer
200.506	2	Rot	2.5	–	–	–	–	Isolated Mixer
254.200	2	Rot	2.5	0.925	Long	0.85	HW	
253.200	2	Rot	2.5	0.925	Long	0.90	HW	
252.200	2	Rot	2.5	0.925	Long	0.95	HW	
252.201	2	Rot	2.5	0.925	Long	0.95	HW	
251.200	2	Rot	2.5	0.925	Long	1.00	HW	
252.100	2	Rot	2.5	1.00	Long	0.95	HW	
252.300	2	Rot	2.5	0.85	Long	0.95	HW	
273.200	2	Rot	2.5	0.90	Long	0.95	13mm SiC	
272.200	2	Rot	2.5	0.95	Long	0.95	13mm SiC	
272.100	2	Rot	2.5	1.00	Long	0.95	13mm SiC	
272.300	2	Rot	2.5	0.85	Long	0.95	13mm SiC	
262.200	2	Rot	2.5	0.925	Long	0.95	7mm SiC	
292.200	2	Rot	2.5	0.925	Long	0.95	13mm SiC	HW Trays Replace Small Lined Trays Near Mixer
262.202	2	Rot	2.5	0.925	Long	0.95	7mm SiC	Mixer Exit Rakes

Table 4.3, DSM Configurations Tested

DSM MIXERS								
Configuration	Mixer	Style	SAR	PEN	Length	MAR	Liner	Other
400.506	4	Aero	2.5	–	–	–	–	Isolated Mixer
473.546	4	Aero	2.5	1.00	Long	0.90	13mm SiC	Flow Tube
453.576	4	Aero	2.5	1.00	Long	0.90	HW	Nozzle Exit Rake Survey
453.506	4	Aero	2.5	1.00	Long	0.90	HW	
452.506	4	Aero	2.5	1.00	Long	0.95	HW	
473.506	4	Aero	2.5	1.00	Long	0.90	13mm SiC	
472.506	4	Aero	2.5	1.00	Long	0.95	13mm SiC	
500.000	5	Aero	2.5	–	–	–	–	Isolated Mixer
500.506	5	Aero	2.5	–	–	–	–	Isolated Mixer
553.046	5	Aero	2.5	0.925	Long	0.90	HW	Flow Tube
553.546	5	Aero	2.5	0.925	Long	0.90	HW	Flow Tube
553.056	5	Aero	2.5	0.925	Long	0.90	HW	Flow Tube, Covered Secondary Inlets
554.006	5	Aero	2.5	0.925	Long	0.85	HW	
553.006	5	Aero	2.5	0.925	Long	0.90	HW	
552.000	5	Aero	2.5	0.925	Long	0.95	HW	
551.000	5	Aero	2.5	0.925	Long	1.00	HW	
574.000	5	Aero	2.5	0.925	Long	0.85	13mm SiC	
573.000	5	Aero	2.5	0.925	Long	0.90	13mm SiC	
572.000	5	Aero	2.5	0.925	Long	0.95	13mm SiC	
571.000	5	Aero	2.5	0.925	Long	1.00	13mm SiC	
553.506	5	Aero	2.5	0.925	Long	0.90	HW	
573.506	5	Aero	2.5	0.925	Long	0.90	13mm SiC	
543.006	5	Aero	2.5	0.925	Long	0.90	Foam Metal	
542.006	5	Aero	2.5	0.925	Long	0.95	Foam Metal	
563.006	5	Aero	2.5	0.925	Long	0.90	7mm SiC	
593.005	5	Aero	2.5	0.925	Long	0.90	13mm Sic	HW Trays Replace Small Lined Trays Near Mixer
583.006	5	Aero	2.5	0.925	Long	0.90	7mm SDOF	Felt Metal Face Sheet
552.004	5	Aero	2.5	0.925	Long	0.95	HW	Mixer Exit Rake
573.566	5	Aero	2.5	0.925	Long	0.90	13mm SiC	Nozzle Exit Rake Survey
573.576	5	Aero	2.5	0.925	Long	0.90	13mm SiC	Nozzle Exit Rake Survey
573.586	5	Aero	2.5	0.925	Long	0.90	13mm SiC	Nozzle Exit Rake Survey

Table 4.3, DSM Configurations Tested, Continued

DSM MIXERS								
Configuration	Mixer	Style	SAR	PEN	Length	MAR	Liner	Other
673.546	6	Aero	2.5	0.85	Long	0.90	13mm SiC	Flow Tube
600.506	6	Aero	2.5	–	–	–	–	Isolated Mixer
653.506	6	Aero	2.5	0.85	Long	0.90	HW	
652.506	6	Aero	2.5	0.85	Long	0.95	HW	
673.506	6	Aero	2.5	0.85	Long	0.90	13mm SiC	
672.506	6	Aero	2.5	0.85	Long	0.95	13mm SiC	
653.576	6	Aero	2.5	0.85	Long	0.90	HW	Nozzle Exit Rake Survey
853.046	8	Aero	2.3	0.925	Long	0.90	HW	Flow Tube
800.000	8	Aero	2.3	–	–	–	–	Isolated Mixer
800.506	8	Aero	2.3	–	–	–	–	Isolated Mixer
853.006	8	Aero	2.3	0.925	Long	0.90	HW	
852.006	8	Aero	2.3	0.925	Long	0.95	HW	
873.006	8	Aero	2.3	0.925	Long	0.90	13mm SiC	
872.006	8	Aero	2.3	0.925	Long	0.95	13mm SiC	
973.546	9	Aero	2.9	0.925	Long	0.90	13mm SiC	Flow Tube
900.500	9	Aero	2.9	–	–	–	–	Isolated Mixer
900.506	9	Aero	2.9	–	–	–	–	Isolated Mixer
953.506	9	Aero	2.9	0.925	Long	0.90	HW	
952.506	9	Aero	2.9	0.925	Long	0.95	HW	
973.506	9	Aero	2.9	0.925	Long	0.90	13mm SiC	
972.506	9	Aero	2.9	0.925	Long	0.95	13mm SiC	
971.506	9	Aero	2.9	0.925	Long	1.00	13mm SiC	
972.606	9	Aero	2.9	0.925	Long	0.95	13mm SiC	Inlet Lip
982.506	9	Aero	2.9	0.925	Long	0.95	7mm SDOF	Felt Metal Face Sheet
932.506	9	Aero	2.9	0.925	Long	0.95	13mm SDOF	Porous Face Sheet
953.576	9	Aero	2.9	0.925	Long	0.90	HW	Nozzle Exit Rake Survey
952.576	9	Aero	2.9	0.925	Long	0.95	HW	Nozzle Exit Rake Survey
973.576	9	Aero	2.9	0.925	Long	0.90	13mm SiC	Nozzle Exit Rake Survey
972.576	9	Aero	2.9	0.925	Long	0.95	13mm SiC	Nozzle Exit Rake Survey

Table 4.3, DSM Configurations Tested, Continued

HAM MIXERS								
Configuration	Mixer	Style	SAR	PEN	Length	MAR	Liner	Other
100.000	1	Cubic	–	–	–	–	–	Cubic Nozzle Reference
2000.000	20	ASME	–	–	–	–	–	ASME Nozzle Reference
0.020	–	–	–	–	–	–	–	Strut Drag Tare
2132.036	–	–	–	–	120"	0.95	–	Nozzle Drag Tare
300.000	3	Aero	2.5	–	–	–	–	Isolated Mixer
312.006	3	Aero	2.5	1.00	120"	0.95	HW	
322.006	3	Aero	2.5	1.00	120"	0.95	13mm SiC	
412.006	4	Aero	2.5	0.925	120"	0.95	HW	
452.006	4	Aero	2.5	0.925	160"	0.95	HW	
422.006	4	Aero	2.5	0.925	120"	0.95	13mm SiC	
472.006	4	Aero	2.5	0.925	160"	0.95	13mm SiC	
473.006	4	Aero	2.5	0.925	160"	0.90	13mm SiC	
422.106	4	Aero	2.5	0.925	120"	0.95	13mm SiC	Chevron #7
472.106	4	Aero	2.5	0.925	160"	0.95	13mm SiC	Chevron #7
452.056	4	Aero	2.5	0.925	160"	0.95	HW	Mixer Exit Rake
472.076	4	Aero	2.5	0.925	160"	0.95	13mm SiC	Nozzle Exit Rake Survey
473.006	4	Aero	2.5	0.925	160"	0.90	13mm SiC	
800.000	8	Aero	2.9	–	–	–	–	Isolated Mixer
812.006	8	Aero	2.9	0.925	120"	0.95	HW	
852.006	8	Aero	2.9	0.925	160"	0.95	HW	
842.006	8	Aero	2.9	0.925	120"	0.95	HW	Porous Tray Hardwall
822.006	8	Aero	2.9	0.925	120"	0.95	13mm SiC	
872.006	8	Aero	2.9	0.925	160"	0.95	13mm SiC	
822.106	8	Aero	2.9	0.925	120"	0.95	13mm SiC	Chevron #7
872.106	8	Aero	2.9	0.925	160"	0.95	13mm Sic	Chevron #7
852.056	8	Aero	2.9	0.925	160"	0.95	HW	Mixer Exit Rake
822.076	8	Aero	2.9	0.925	120"	0.95	13mm SiC	Nozzle Exit Rake Survey
1000.000	10	Aero	2.5	–	–	–	–	Isolated Mixer
1012.006	10	Aero	2.5	0.85	120"	0.95	HW	
1022.006	10	Aero	2.5	0.85	120"	0.95	13mm SiC	
2100.000	21	NRA	2.8	–	–	–	–	Isolated Mixer
2112.006	21	NRA	2.8	1.00	120"	0.95	HW	
2122.006	21	NRA	2.8	1.00	120"	0.95	13mm F.M.	Foam Metal Liner

Table 4.4, HAM Configurations Tested

```
                    Naming Conventions for the 1995 HSCT GEN2 DSM Nozzle Test in LSAF

                    Run Number XXXX to be assigned sequentially to each condition

                                        Configuration Number

                                              AABC.DEF
                                              | || |||
Nozzle/Mixer: AA --------------------/ || ||\----------- BLC / Mixer Rakes: F
00      None                                 || ||            0 No         No
01-09   Mixers 1 - 9 @ 15 degrees            || ||            1 Pos 1      No
10      ASME                                 || ||            2 No         Pos 1
11-19   Mixers 1 - 9 @ 00 degrees            || ||            3 Pos 1      Pos 1
20      RC                                   || ||            4 No         Pos 2
29      Mixer 9 SLA                          || ||            5 Pos 2      Pos 3
                                             || ||            6 Pos 3      No
                                             || ||
Flap Length / Acoustic Liner: B -------/| |\--- Flow Tube / Model Drag Tare: E
0              No Flap, No Liner          | |    0    None
1              Short Flap, Hardwall       | |    1    ASME Strut Drag Tare
2              Short Flap 13 mm SiC       | |    2    GEN2 Strut Drag Tare
3              Eggcrate                   | |    3    GEN2 Nozzle Drag Tare
4              Long Flap 13mm Foam Metal  | |    4    Flow Tube Calibration
5              Long Flap Hardwall         | |    5    Flow Tube Covered Inlet
6              Long Flap 7 mm SiC         | |    6    Exit Survey, Pt,Tt,Ps Probe
7              Long Flap 13 mm SiC        | |    7    Exit Survey, 5 H Pt Probe
8              Long Flap SDOF             | |
9              Long Flap Hardwall/13 mm   | |
                                          | |
MAR: C --------------------------------/ \------------- Flapper/Insert: D
0  No Flaps                                              0  None/No Insert
1  1.00                                                  1  Pen=1.00/No Insert
2  0.95                                                  2  Pen=0.925/No Insert
3  0.90                                                  3  Pen=0.85/No Insert
4  0.85                                                  4
5  0.925                                                 5  None/M=.32 Insert
6  0.975                       Condition Number          6  Inlet Lip/M=.32 Insert

                                             AAB
                                             | |
Throttle Condition (NPR): AA ----------/ \-------- Mach/Primary Gas Cond: B
AA  NPR                                            B Mach      Cycle
00  0.00  (Drag Tare)                              0 0.00
10  1.00  (Noise Floor)                            1 0.12      3765
15  1.52                                           2 0.245
19  1.86
20  1.99                                           3 0.00
22  2.25                                           4 0.12      Cold
25  2.48                                           5 0.245
26  2.64
30  2.96                                           6 0.00      Off Cycle Hot
32  3.20                                           7 0.32      All Hot Runs
34  3.43                                           8 0.245     Off Cycle Hot
40  4.00                                           9 0.32      All Cold Runs

Table Generated by: D. Forsyth
Last Modifed: 3/13/96, D. Arney
```

Figure 4.2, Naming Convention for DSM Testing, LSAF 1032

```
                      Naming Conventions for the 1996HSCT HAM Nozzle Test in LSAF
                     Run Number XXXX to be assigned sequentially to each condition
                             Configuration Number
                                   AABC.DEF
                                   | || |||
Nozzle/Mixer: AA --------------------/ || ||\----------- BLC / Mixer Rakes: F
00     None                            || ||              0 No        No
01  Cubic                              || ||              1 Pos 1     No
03  Mixer 3                            || ||              2 No        Pos 1
04  Mixer 4                            || ||              3 Pos 1     Pos 1
08  Mixer 8                            || ||              4 No        Pos 2
10  Mixer 10                           || ||              5 Pos 2     Pos 3
20  ASME                               || ||              6 Pos 3     No
21  Mixer 21, NRA                      || ||
                                       || ||
Flap Length / Acoustic Liner: B -------/| |\--- Model Drag Tare / Survey's: E
0              No Flap, No Liner        | |    0    None
1              120" Flap, Hardwall      | |    1    ASME Strut Drag Tare
2              120" Flap, SiC           | |    2    HAM Strut Drag Tare
3              120" Flap, Foam Metal    | |    3    HAM Nozzle Drag Tare
4              120" Flap, Porous Tray/HW.| |
5              160" Flap Hardwall       | |    5    Mixer Exit Rakes
6                                       | |    6    Exit Survey, Pt,Tt,Ps Probe
7              160" Flap, SiC           | |    7    Exit Survey, 5 H Pt Probe
                                        | |
                                        | |
                                        | |
MAR: C ---------------------------------/ \------------- Chevron/Inlet: D
0  No Flaps                                             0  No Chevron
1                                                       1  Chevron #7
2  0.95                                                 2  Scab-on-Inlet
3  0.90


                                   Condition Number
                                       AAB
                                       | |
Throttle Condition (NPR): AA ----------/ \-------- Mach/Primary Gas Cond: B
AA  NPR                                            B Mach      Cycle
00  0.00  (Drag Tare)                              0 0.000   |
10  1.00  (Noise Floor)                            1 0.245   | 3765,3570.80,L1M
15  1.52                                           2 0.320   |
19  1.86
20  1.99                                           3 0.000   |
22  2.25                                           4 0.245   | Cold
25  2.48                                           5 0.320   |
26  2.64
30  2.96                                           6 0.00    |
32  3.20                                           7 0.245   | Off Cycle Hot
34  3.43                                           8 0.320   |
40  4.00                                           9
```

Figure 4.3, Naming Convention for HAM Testing, LSAF 1039

5.0 Test Results

Two mixer/ejector models were tested during the Gen 2.0 LSAF test, the DSM and the HAM. The DSM model had an aspect ratio of 1.17, mixing plane area of 58 sq. inches, and a short, compact secondary inlet. The HAM model had an aspect ratio of 1.5, mixing plane area of 64.7 sq inches, and a longer secondary inlet with shallower inlet ramp angles. The geometry of these mixers is discussed in section 2.0. The DSM and the HAM were both tested with a series of best aero mixers that mimic the same design parameters, but are implemented with the different aspect ratio's. In addition to the best aero mixers, two vortical style of mixers were tested, the DSM rotating chute concept and the HAM NRA concept. Again, section 2 discusses the mixer geometries.

Figure 5.1 shows a sampling of the mixer configuration results obtained during the Gen 2.0 test series. The figure shows thrust coefficient, cfn vs single engine EPNL for the key cutback and sideline design conditions. The EPNL was calculated for a full scale airplane. All the configurations shown in the figure are treated with 13mm (about 3.6 inches full scale) bulk absorber. Improvements in mixer/ejector performance with each progression of mixers tested and lessons learned can be seen. The DSM rotating chute mixers 1 and 2 and the HAM NRA mixer 21 show the status of the nozzle development at the start of the Gen 2.0 test. All three mixers had low thrust performance and for the DSM mixers, high noise levels. With the DSM best aero mixers (5 and 9 on the chart), a large improvement in thrust performance was seen. A small noise improvement relative to the DSM mixers 1 and 2 was also seen. The HAM best aero mixers (4 and 8 on the chart) showed further improvement in noise while maintaining the higher thrust performance of the DSM best aero mixers. Increasing the length of the mixing duct by about 5.7 inches model scale (120 inch full scale flap to 160 inch) and adding chevrons to the nozzle exit yielded additional noise reduction without large thrust losses. The HAM best aero mixer 8 with long flaps and chevrons showed the best overall aero/acoustic performance.

Figure 5.2 illustrates the difference in exit velocity profile between the HAM and the DSM mixers. The HAM mixer is better mixed with velocity variations from 1550 to 1800 ft/s in the core region of the flow. The velocity variation with the DSM was larger from 1400 to 1800 ft/s. Both mixers showed a large low flow region along the middle of the sidewalls. This region seems to be a little larger for the HAM than the DSM. The low velocity flow in this region is lost thrust and is one area of potential improvement. Additional exit and internal survey data is provided in References 5 – 13.

Several key parameters were evaluated during the Gen 2.0 test. These parameters include, SAR, MAR, Penetration, liners, mixing duct length, mixer shape, chevrons, primary gas temperature, and tunnel Mach number. The results section is divided up to discuss the key parameters individually. Pertinent aerothermal data and sample noise spectra follow each discussion section.

Figure 5.3 depicts the flight geometry used in the noise extrapolation in this section. EPNLs and spectra are for single engines in level flight with no shielding or reflections as was simulated in LSAF. Note that the range of polar angles measured (50°–145°) is smaller than the range of polar angles shown in spectra (60°–150°). Data beyond the range of polar measurements is created by extrapolating the last angle's source spectrum to the new angle's propagation distance and atmospheric absorption. This technique is conservative, as the true source strength would likely have decreased at the new angle. Note also that the standard 1629' distance to the flight axis (taken from the sideline flight profile) results in a higher altitude at the flyover point for cutback than the plane is likely to reach. But the comparisons of the mixers are not compromised by this. And using a common distance allows the azimuthal variation of noise to be more easily seen.

Figure 5.4 provides a guide to reading the spectra plots shown in the rest of this section. The features highlighted in the sample spectra can be seen in many of the spectra that follow. Spikes in a spectrum like the burner tone shown, are tones that should not appear in the full scale nozzle spectra. Also evident is the high frequency noise of the mixer, and the benefit of the treated ejector lining. Most importantly, the fully mixed jet noise is low. This is the whole purpose of the mixer/ejector.

This portion of the summary document highlights the more important findings of the test. Several HSCT Coordination memo's have been released that more fully document various elements of the data. Reference 14 and 15 contains plots of mixing duct static pressures for most of the HAM and DSM conditions tested. Other CMs of like nature will follow. Also, the entire data base is available on electronic media for retrieval from either NASA or Boeing.

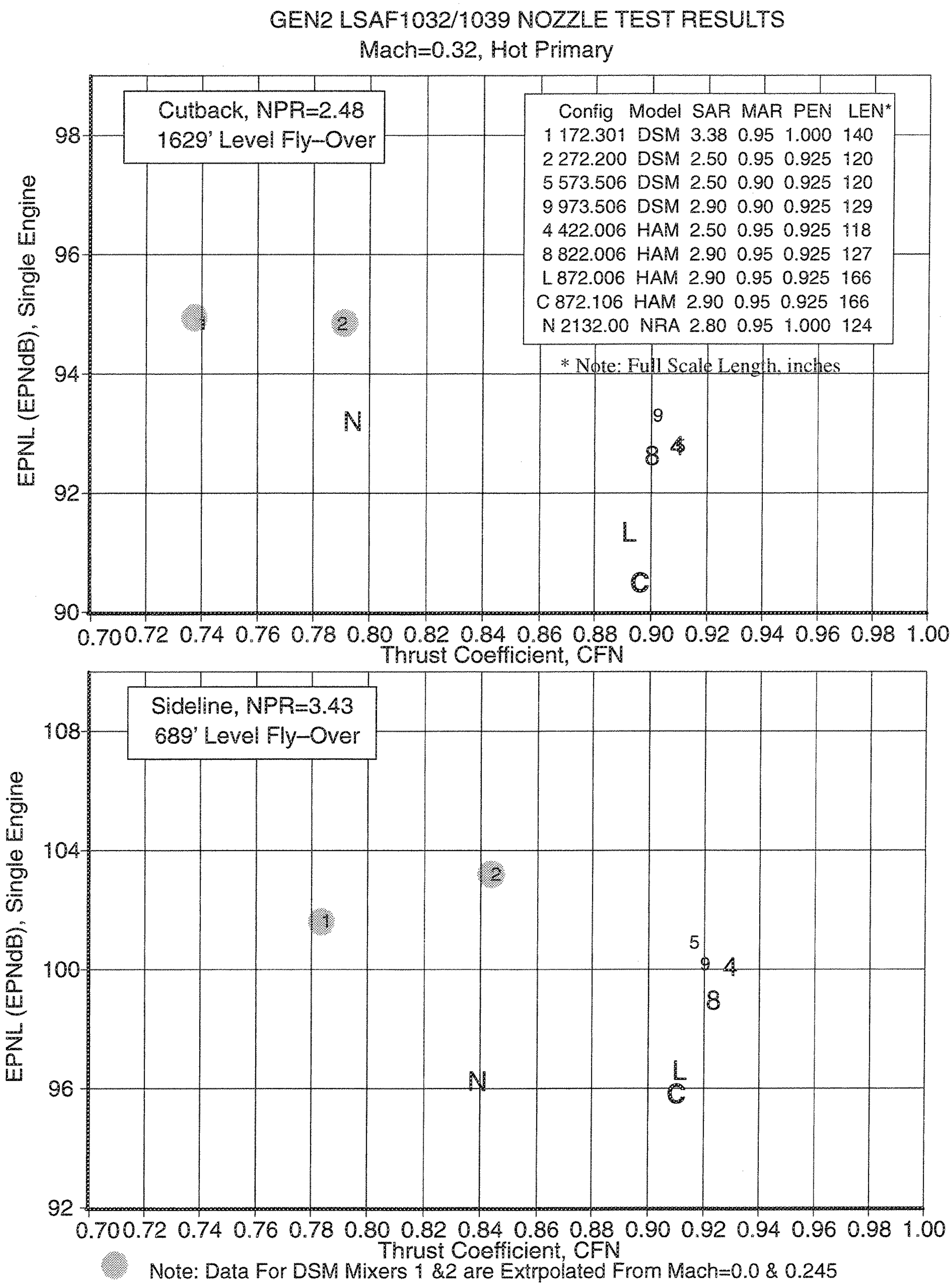


Figure 5.1, Overall Test Results, Mach=0.32, Hot Primary

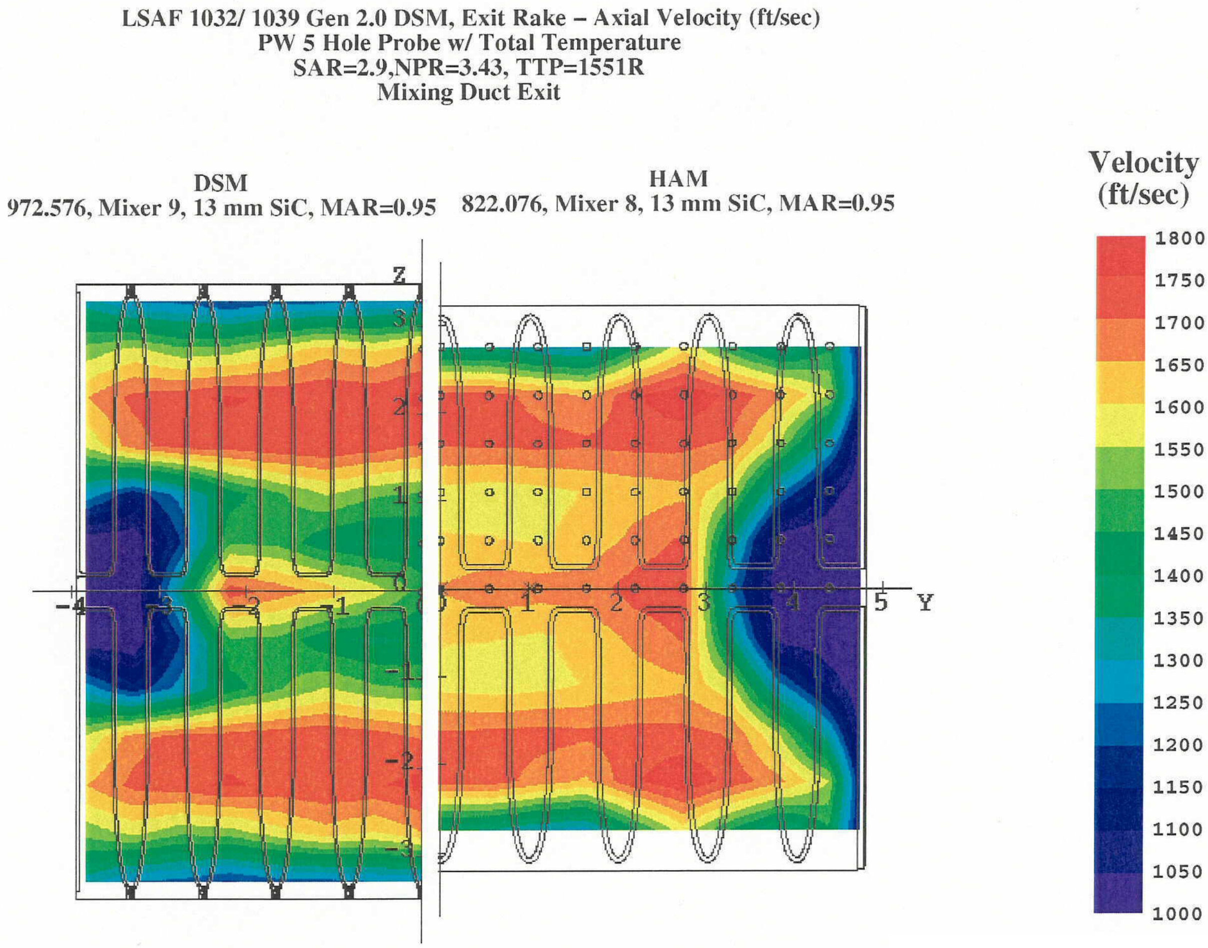
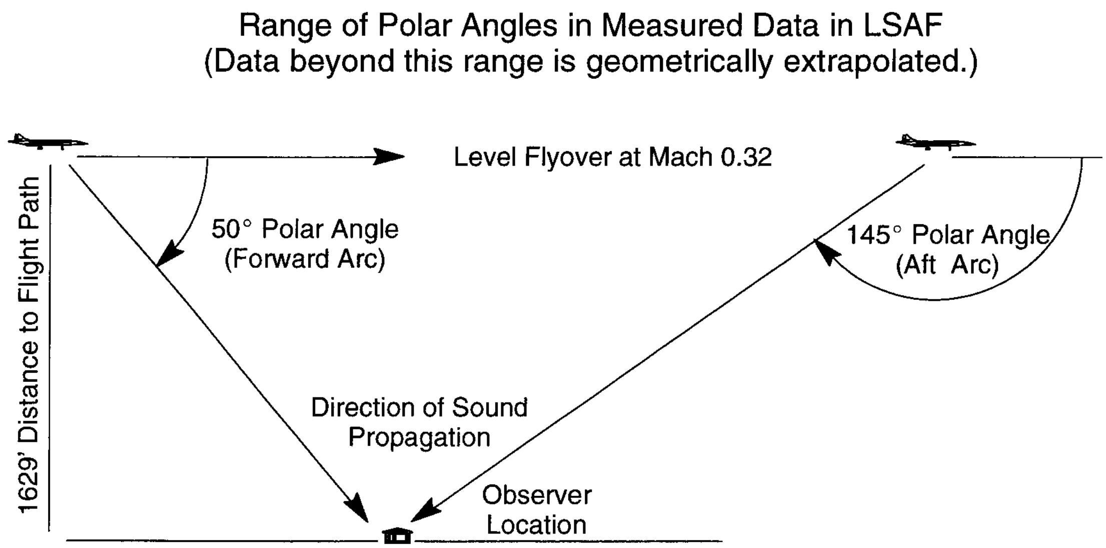
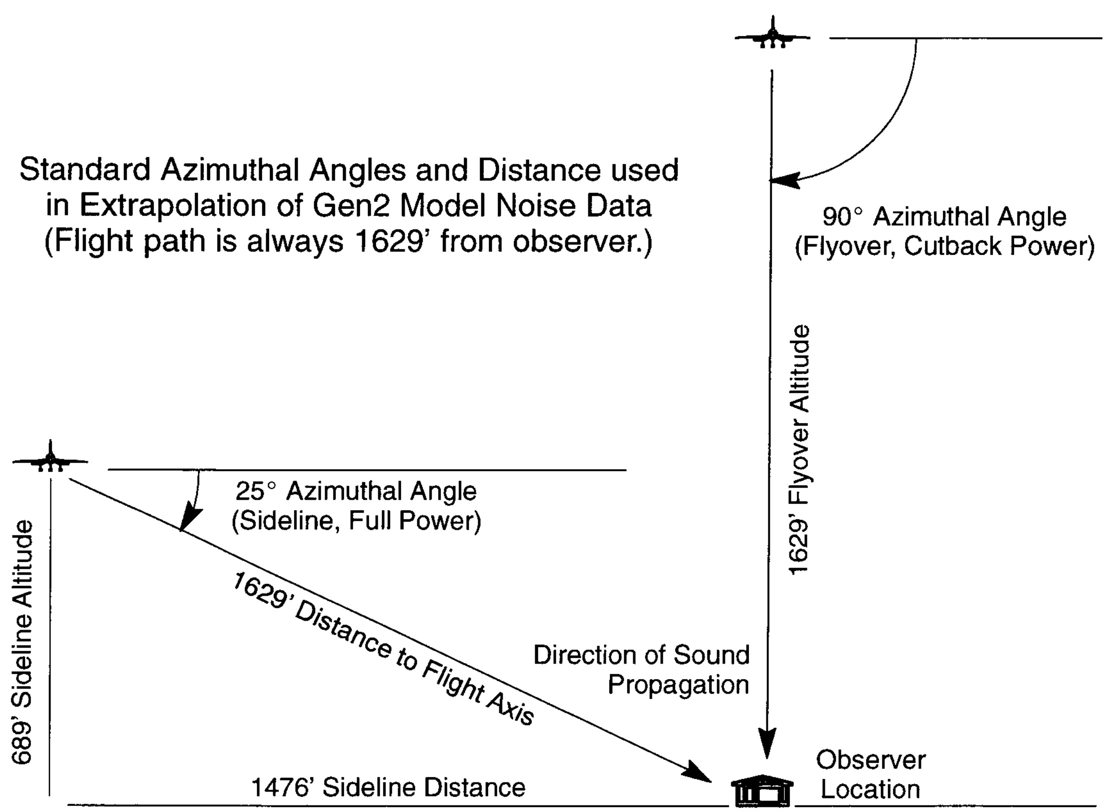


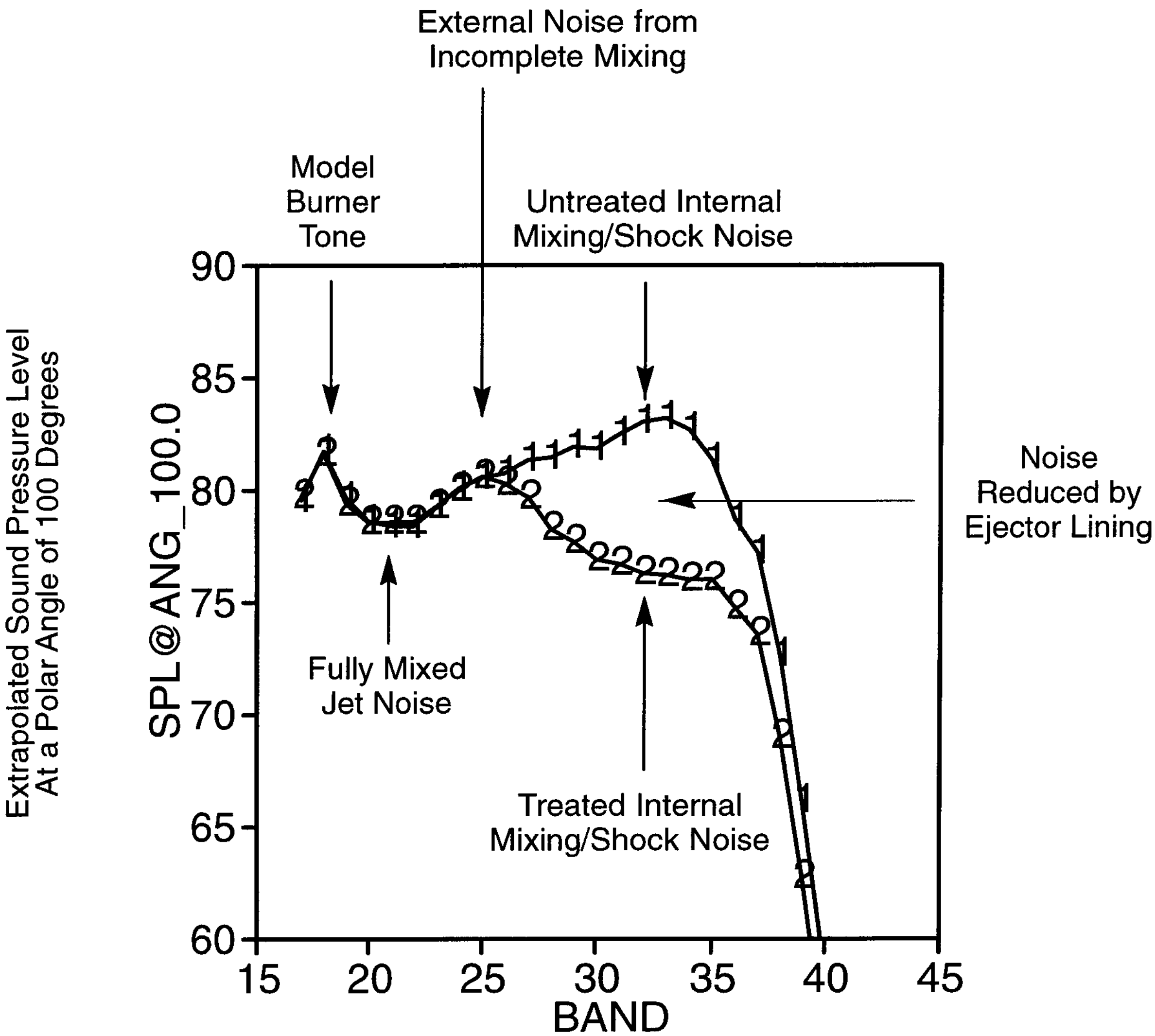
Figure 5.2, Exit Velocity Profile Comparison, DSM Mixer 9 vs HAM Mixer 8, SAR=2.9, PEN=0.925, MAR=0.95, Mach=0.32, Hot Primary



All Extrapolations are Free Field Level Flyovers 1629 feet from Flight Axis to Observer.



Spectral Features Shown For HAM Mixer 8 Extrapolated to 689' Sideline at Full Power



Third Octave Band Number
Frequency in Hz = $10^{(BAND/10)}$

PNLT is the log sum of NOY weighted SPLs and tone penalties at each polar angle.
EPNL is the log sum of flyover time weighted PNLTs within 10dB of the peak PNLT.

5.1 Effect of Mach Number

When the Gen 2.0 test began, the LSAF's maximum free jet Mach number was 0.245. Since the design condition for the airplane was at Mach 0.32, some extrapolation of the data is needed to estimate results at Mach 0.32. Midway through the test, the free jet nozzle was modified to allow testing up to Mach 0.32. Since much of the data for the DSM mixers was tested only to Mach 0.245, extrapolation of these data was done to compare with data acquired at Mach 0.32. Figures 5.5 and 5.6 show the trend with Mach number for the thrust coefficient, mass flow ratio and noise (EPNL) for the cutback and sideline design conditions. The information shown for DSM mixer 8, Mach=0.32, was extrapolated from the Mach 0.0 and 0.245 data. A smooth transition with Mach number is evident for all the parameters shown.

Figure 5.7 shows static pressure profiles for DSM mixer 5, configuration 573.506, hot primary, for Mach 0.0, 0.245, and 0.32. A softening of the mode switch (the transition from subsonic to supersonic flow in the mixing duct) is apparent with increasing Mach number. At Mach=0.0 and NPR=4.0, the static pressures show supersonic mode operation through much of the mixing duct. At Mach=0.32, the supersonic mode is limited to the first one third of the duct with subsonic mode through most of the mixing duct. At NPR=3.43 and below, the dominant mode for all Mach numbers is subsonic.

Figure 5.8 shows the effect of increasing Mach number on the extrapolated noise spectra at sideline at the full power point for DSM mixer 9. The upper two spectra would be radiated in front of the aircraft. The middle two spectra would be radiated soon after the aircraft passed the observer. And the bottom spectra would be radiated well after the flyby. The major effect of increasing tunnel speed (and therefore flight speed) is to reduce the low frequency noise due to the mixed jet. This is especially evident in the aft arc (lower plots). Some of the differences in the high frequencies in the forward arc may be due to the tunnel shear layer correction which is not applied for the static data (zeros).

Figure 5.9 shows the effect of increasing Mach number on the extrapolated noise spectra at cutback at the flyover point for DSM mixer 9. The effect of increasing tunnel speed on the spectra is similar to that seen at sideline.

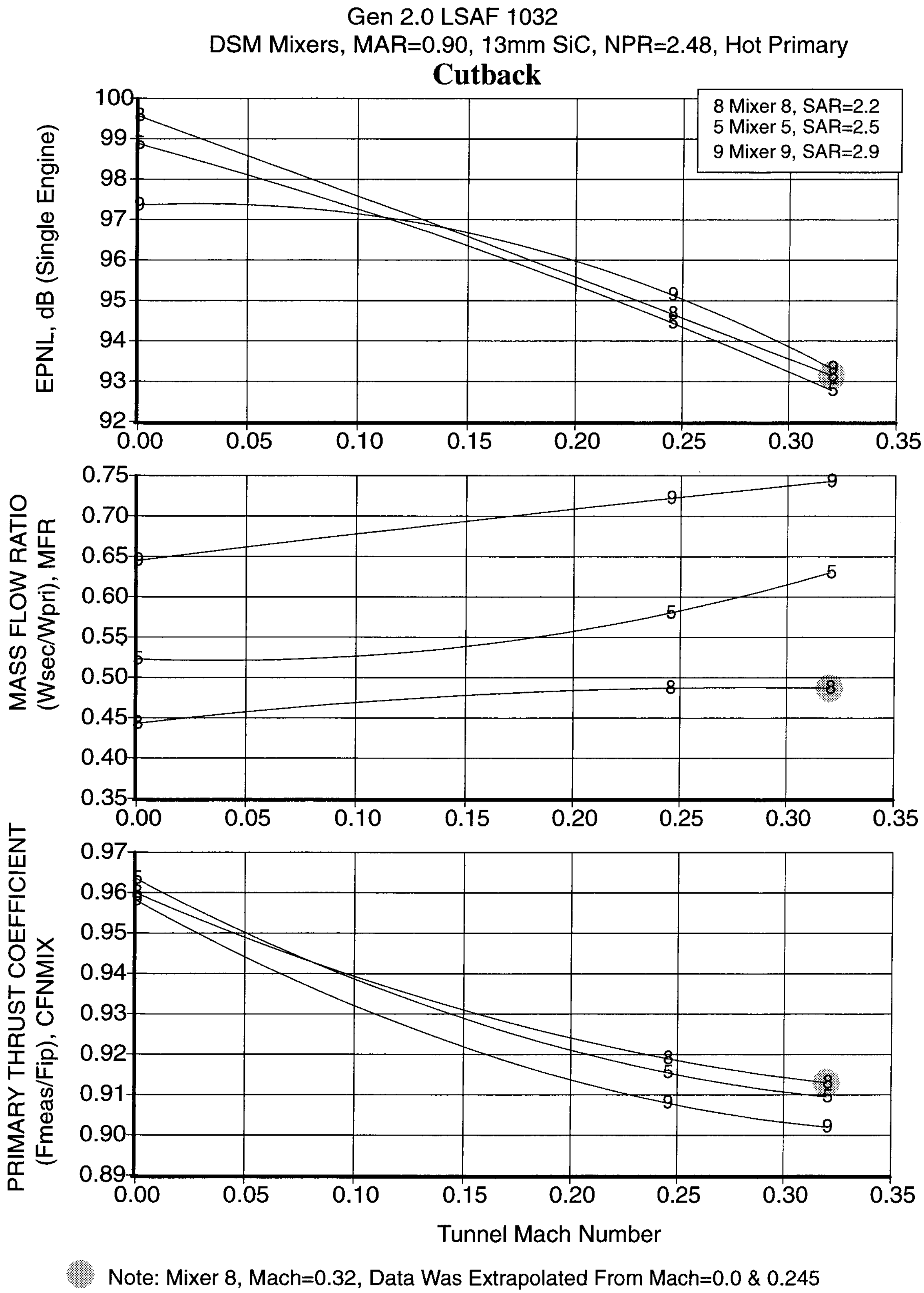


Figure 5.5, Effect of Mach Number, DSM, MAR=0.90, 13mm SiC, NPR=2.48 Hot Primary

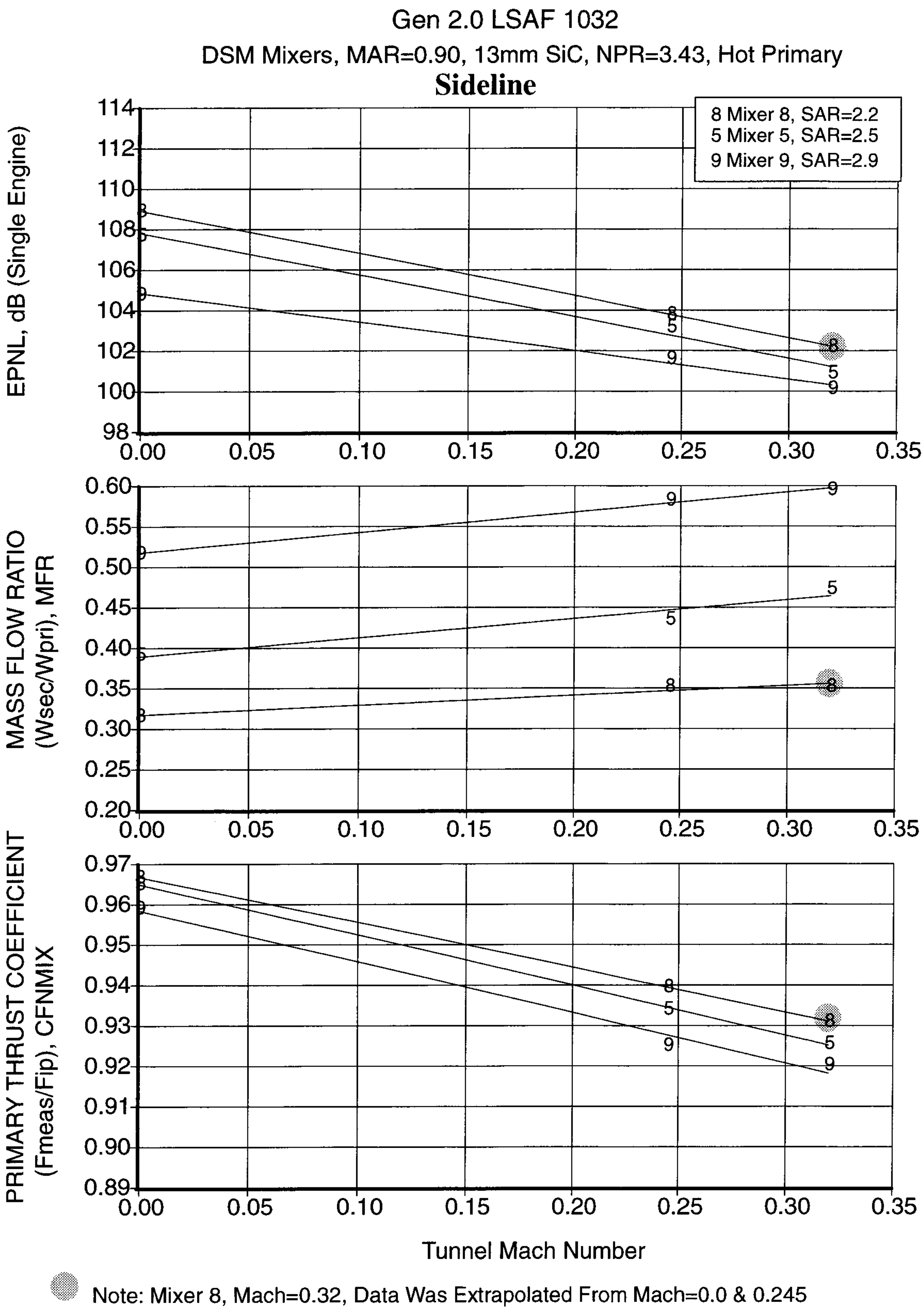


Figure 5.6, Effect of Mach Number, DSM, MAR=0.90, 13mm SiC, NPR=3.43 Hot Primary

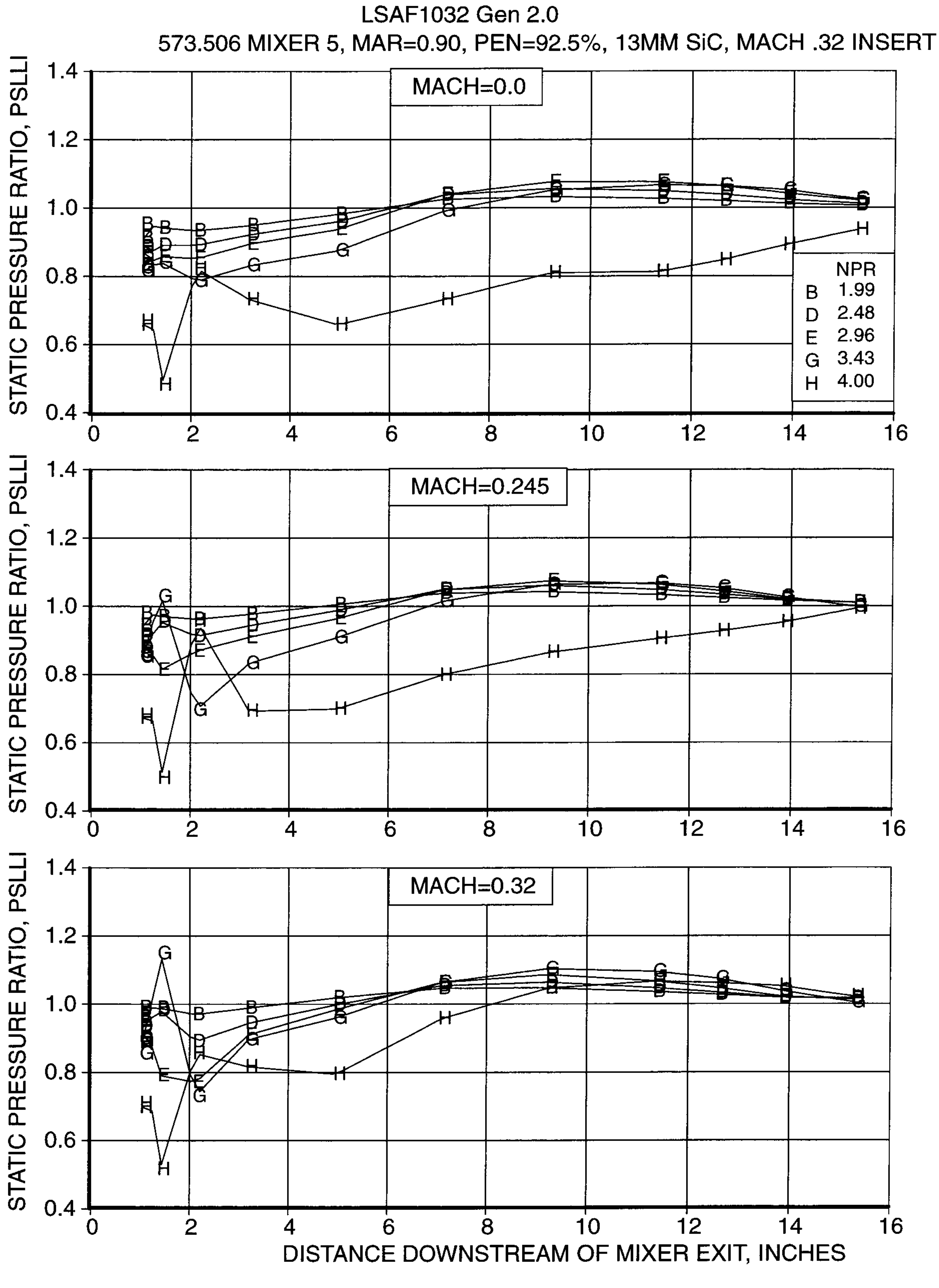


Figure 5.7, Effect of Mach Number, DSM, MAR=0.90, 13mm SiC, Hot Primary

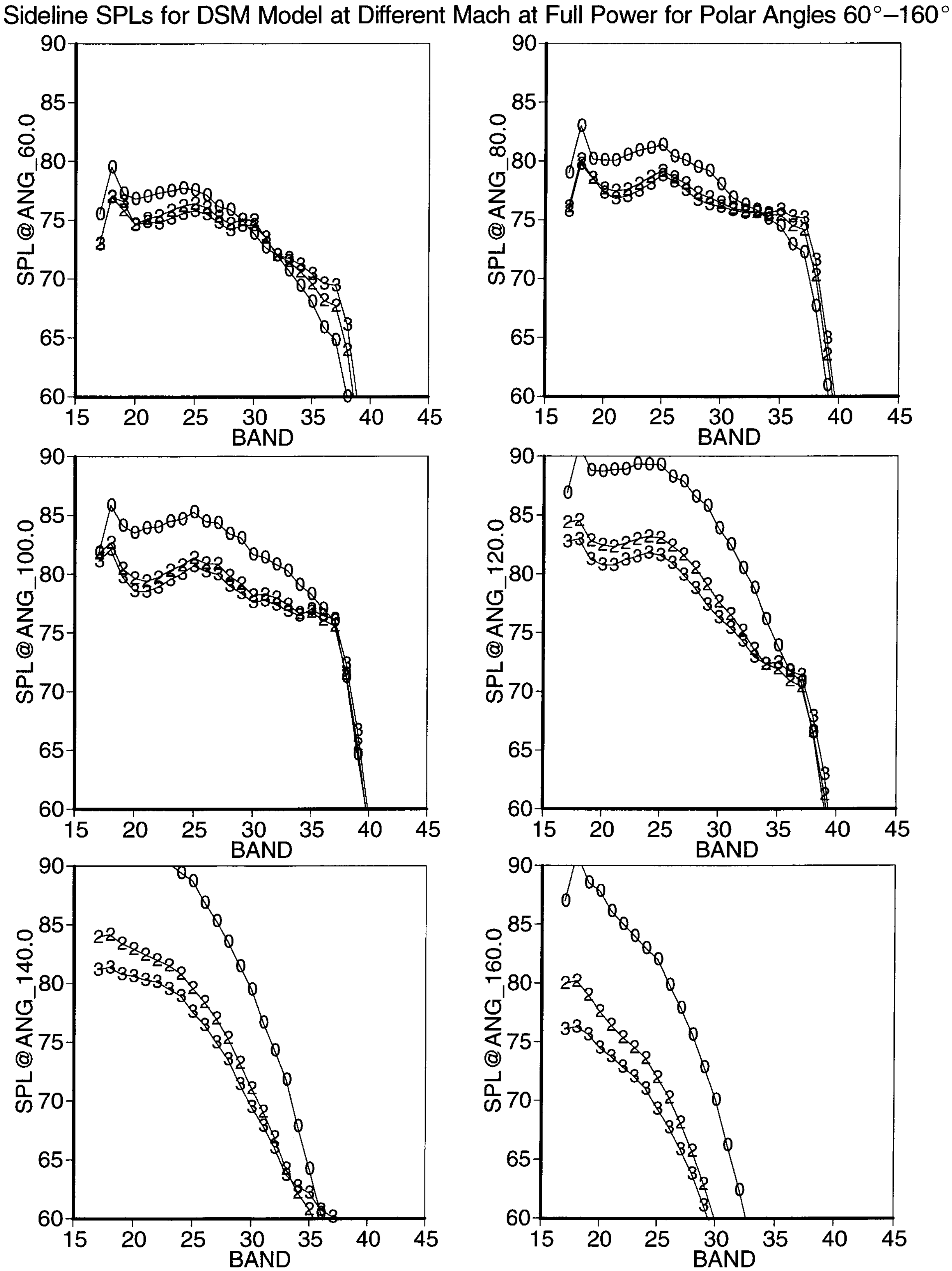


Figure 5.8, Effect of Mach on Extrapolated Spectra, DSM Mixer 9, 13mm SiC, Static (0), Mach 0.245 (2), Mach .320 (3) at NPR 3.43, SAR=2.9, MAR=0.90

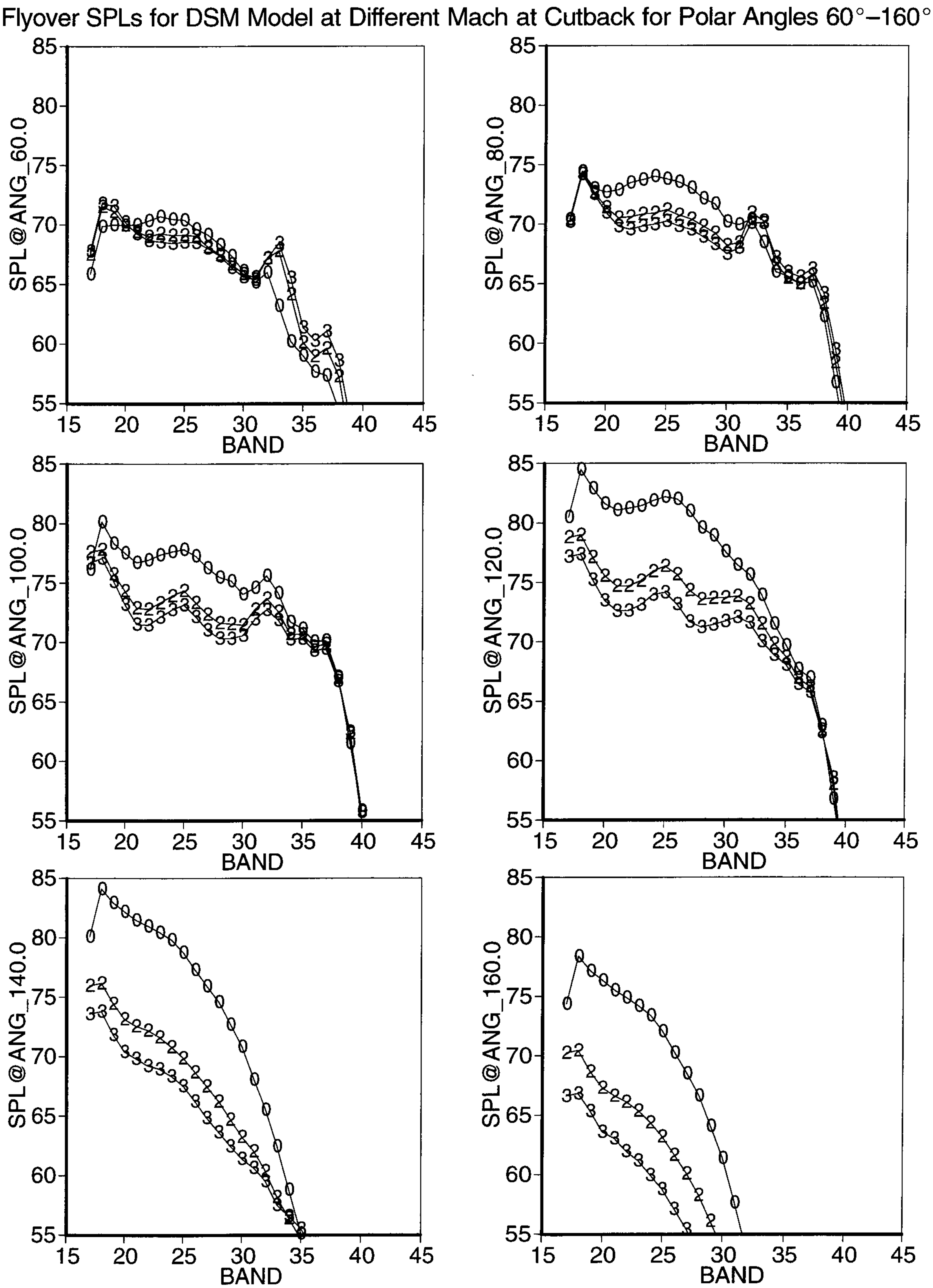


Figure 5.9, Effect of Mach on Extrapolated Spectra, DSM Mixer 9, 13mm SiC, Static (0), Mach 0.245 (2), Mach .320 (3) at NPR 2.48, SAR=2.9, MAR=0.90

5.2 Effect of Primary Temperature

Variation in primary gas temperature was tested with Mixer 5 to help determine its effect on performance. The results are shown in Figure 5.10. No acoustic information were obtained with cold flow (ambient primary temperature). Noise increases with temperature, about 1 EPNdB/270°R for sideline condition and 1 EPNdB/130°R for cutback condition. The corrected mass flow ratio decreases smoothly with primary temperature. This is possibly due to the thermal expansion of the mixer with temperature – which would tend to cause the primary air passages to increase in area, with an associated decrease in secondary area. The thrust coefficient varies most strongly with the primary burner on vs off. With the burner on (hot gas conditions) the thrust coefficient is relatively level. With the burner off (cold gas condition) the level is different, +~1% at sideline and –~0.5% at cutback relative to the burner on conditions.

Figure 5.11 shows the effect of primary temperature on the static pressures in the mixing duct. Little or no temperature effect on the mixing duct static pressures can be seen.

Figure 5.12 shows the effect of increasing primary temperature on the extrapolated noise spectra at sideline at the full power point for DSM mixer 5. Increasing primary temperature increases the low frequency noise due to the mixed jet. This is most evident in the aft arc (lower plots). There does not seem to be a large increase in high frequency mixing noise even though increasing primary temperature for a given NPR increases the relative velocity between the primary and secondary that produces high frequency mixing noise.

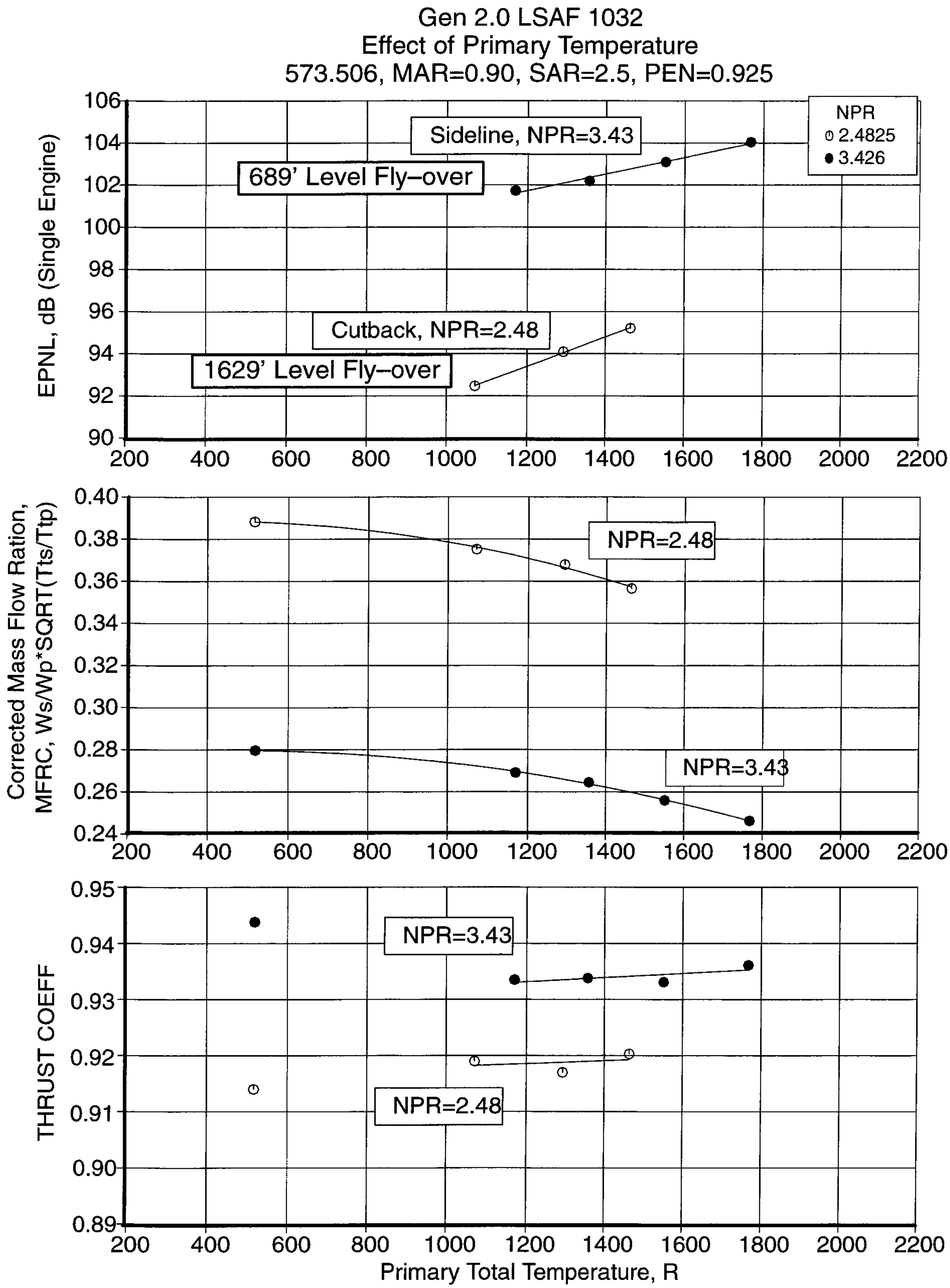


Figure 5.10, Effect of Primary Temperature, DSM Mixer 5, Mach=0.245, 13mm SiC

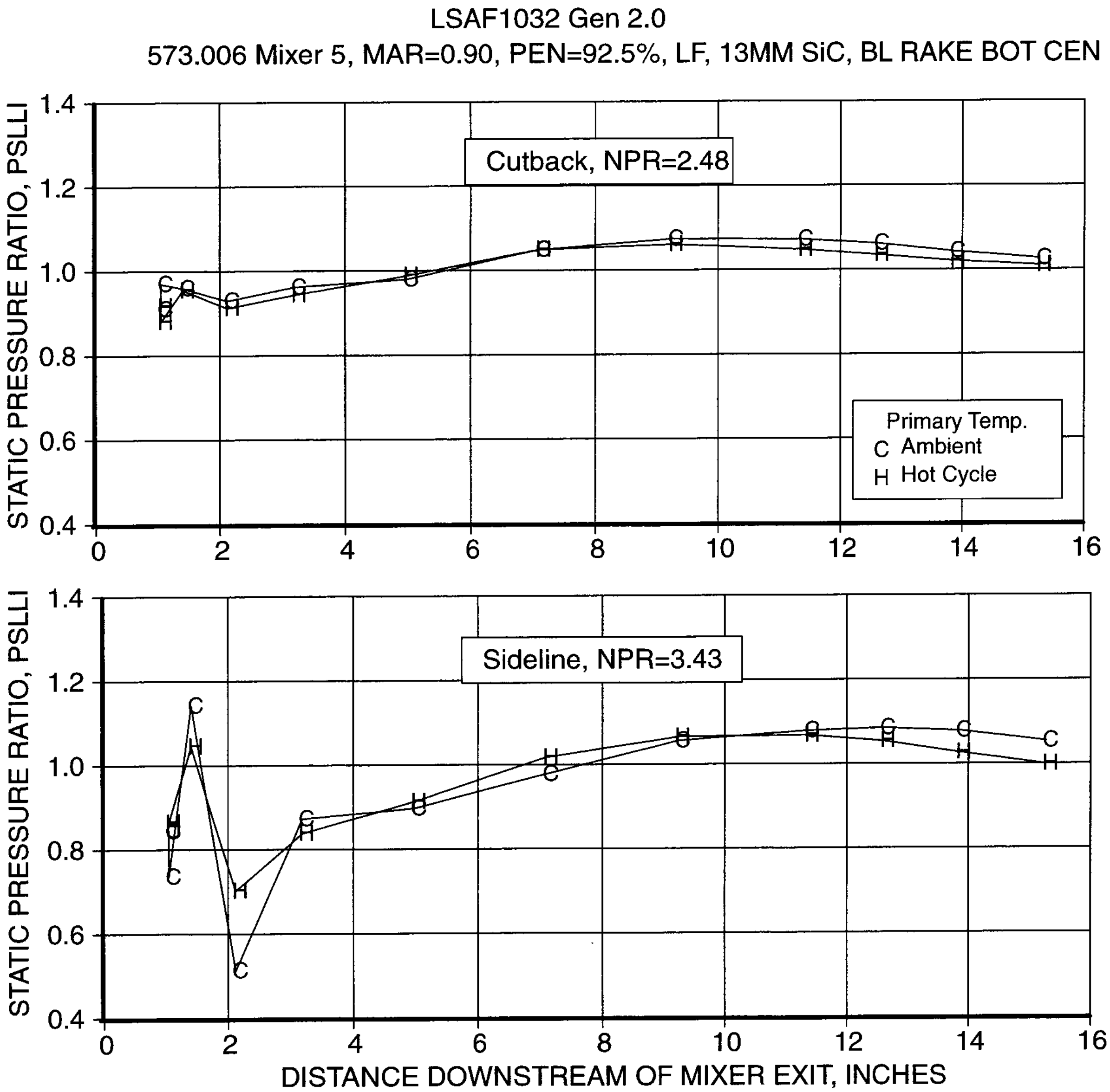


Figure 5.11, Effect of Primary Total Temperature, DSM, Mach=0.245, MAR=0.90, 13mm SiC,

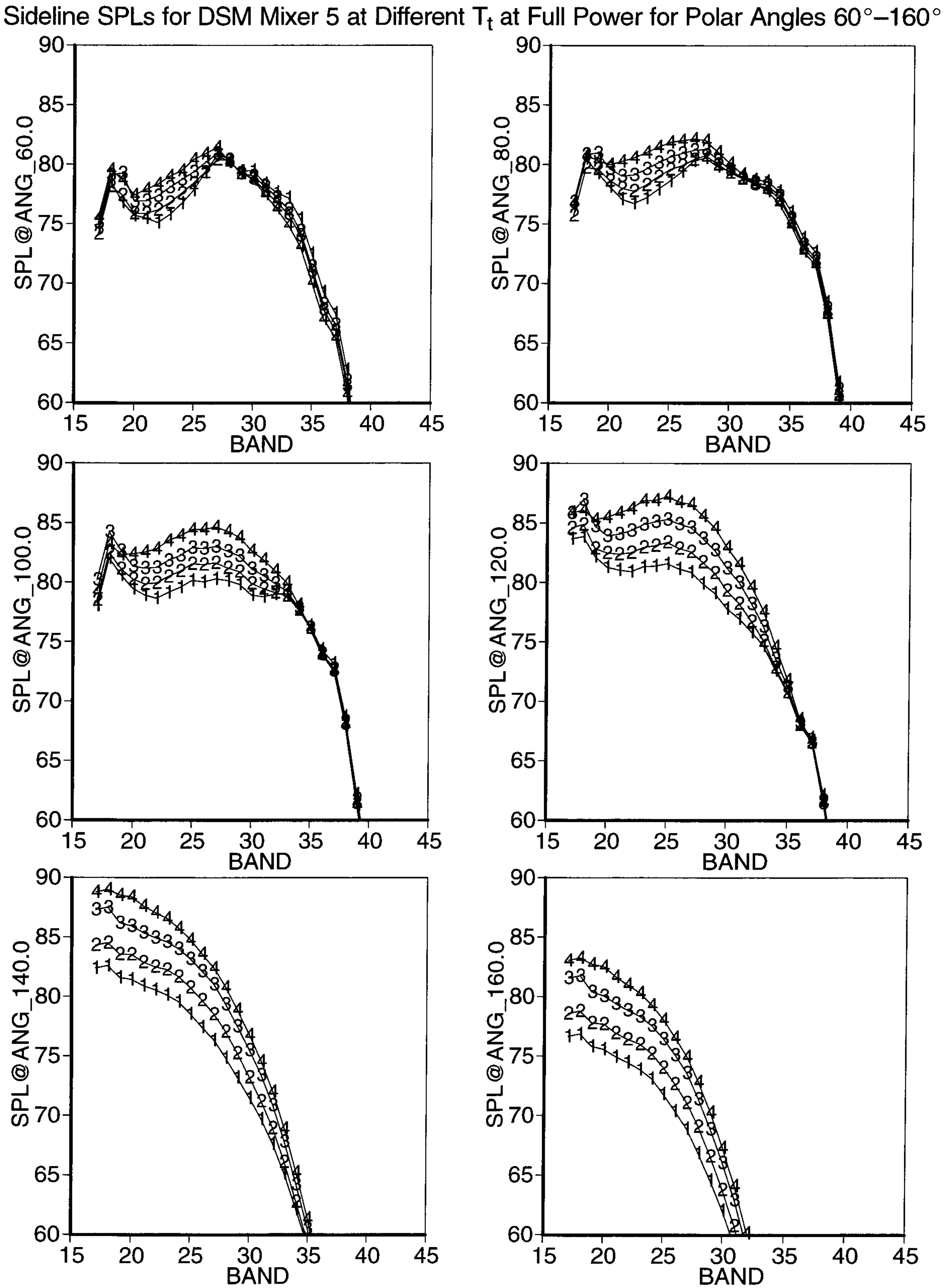


Figure 5.12, Effect of T_t on Extrapolated Spectra, DSM Model, SAR=2.5, MAR=0.9, 13mm SiC, 1169.2°R (1), 1357.9°R (2), 1551.3°R (3), and 1767.6°R (4) at NPR 3.43, Mach=0.245

5.3 Effect of SAR

Figure 5.13 shows the effect of ASAR (aerodynamic suppressor area ratio) on the DSM and HAM best aero mixers (PEN=92.5%, MAR=0.95, hot primary) for thrust, aspiration, and acoustics at the Mach=0.32 cutback and sideline design conditions. The SAR values listed in Table 2.1 reflect the design target, not the actual as–built areas. ASAR is used here because it is closest to the actual as–tested area (includes the effect of thermal expansion).

At constant ASAR, the two models have virtually the same thrust coefficient and aspiration. The HAM nozzle has lower noise at the sideline condition – particularly at the lower ASAR values (ASAR less than 2.9). At the higher ASAR values the difference between the two models becomes small. The cutback noise levels of the two models are even closer. Figure 5.14 shows the same noise and thrust data plotted as a function of mass flow ratio instead of ASAR. Again, the thrust performance for the two models is about the same. Acoustically, the HAM at MAR=0.95 performs like the DSM at MAR=0.90. The effect of ASAR on EPNL for the HAM mixer is ~–3 EPNdB/SAR and ~–6 EPNdB/SAR for the DSM mixer at the sideline condition. The cutback noise is not effected by SAR. The effect of ASAR on thrust is ~–2 CFN%/SAR at both sideline and cutback.

Figure 5.15 shows the effect of SAR on static pressure inside the mixing duct on the DSM for the cutback and sideline conditions. The data shown in the figure is for Mach=0.245, since no data at Mach=0.32 was collected for DSM mixer 8 (SAR=2.2). The row of static pressures illustrated, PSLLI, is located between the two mixer halves on the left sidewall, so it is initially scrubbed with primary airflow. At cutback, the pressures show very little change between the SAR values tested. At sideline both mixer 5 and 8 show supersonic mode flow thru much of the mixing duct. Mixer 9 shows mostly subsonic flow. Figure 5.16 shows the static pressures on the flap, PSLTI, centered behind a secondary lobe. The results show the same trend as was noted in Figure 5.15.

Figure 5.17 shows the effect of SAR on the extrapolated noise spectra at sideline at the full power point for DSM mixers 5 and 9. The effect of increasing SAR is to decrease the low frequency noise due to the mixed jet in the aft arc and reduce the mid frequency peak (probably due to some unmixed supersonic flow) in the forward arc. There is also an increase in high frequency mixing noise at the higher SAR for this model.

Figure 5.18 shows the effect of SAR on the extrapolated noise spectra at cutback at the flyover point for DSM mixers 5 and 9. The effect of increasing SAR at cutback is similar to that seen at sideline. The increase in high frequency mixing noise is even stronger at cutback SAR for this model.

Figure 5.19 shows the effect of SAR on the extrapolated noise spectra at sideline at the full power point for HAM mixers 4 and 8. The effect of increasing SAR again is to decrease the low frequency noise due to the mixed jet in the aft arc and reduce the mid frequency peak in the forward arc. However, there is no increase in high frequency noise at the higher SAR in the HAM model ejector.

Figure 5.20 shows the effect of SAR on the extrapolated noise spectra at cutback at the flyover point for HAM mixers 4 and 8. Increasing SAR decreased the low frequency noise a small amount. However, the high frequency noise at the higher SAR actually fell at cutback power.

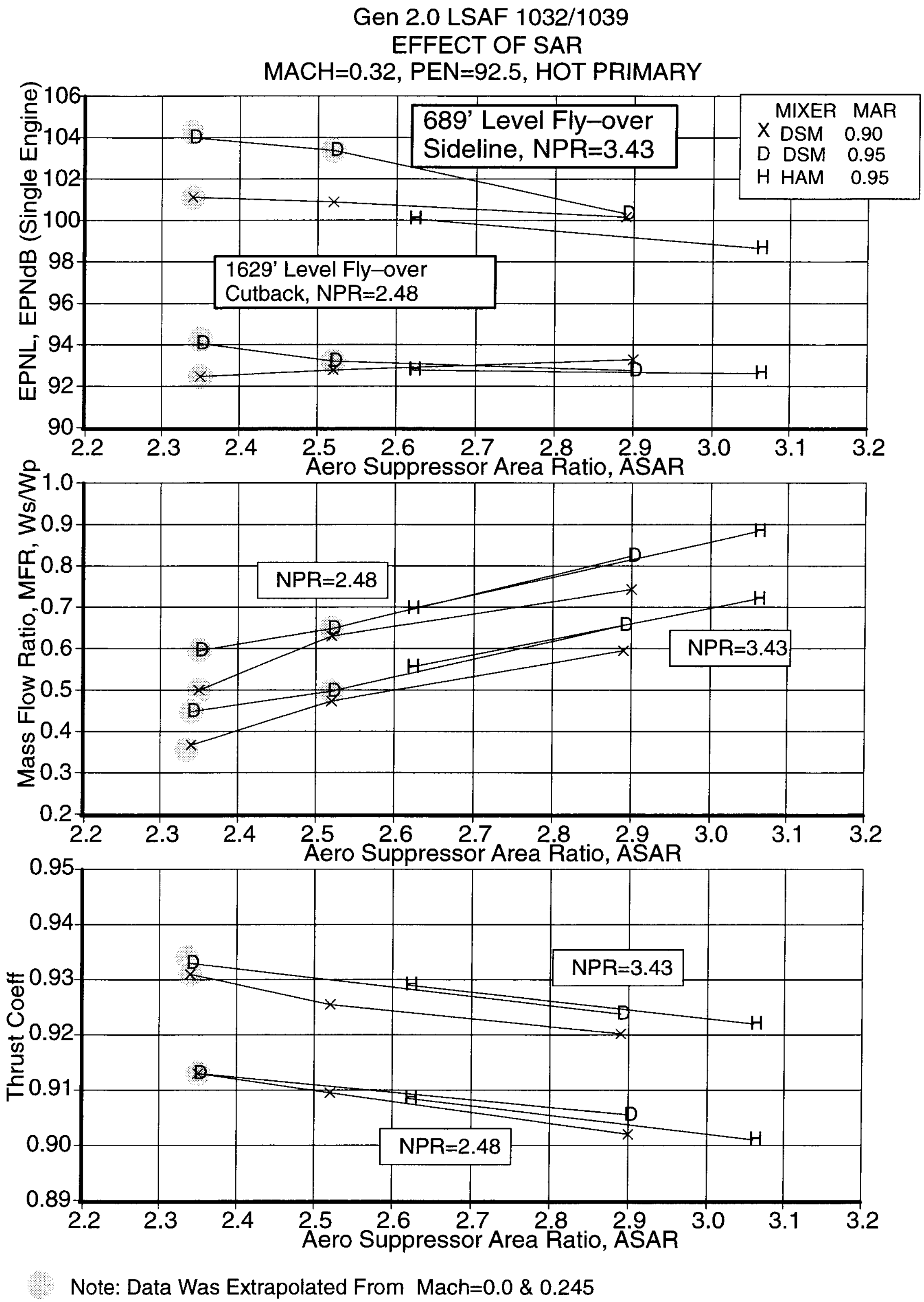


Figure 5.13, Effect of SAR, Mach=0.32, 13mm SiC, Hot Primary

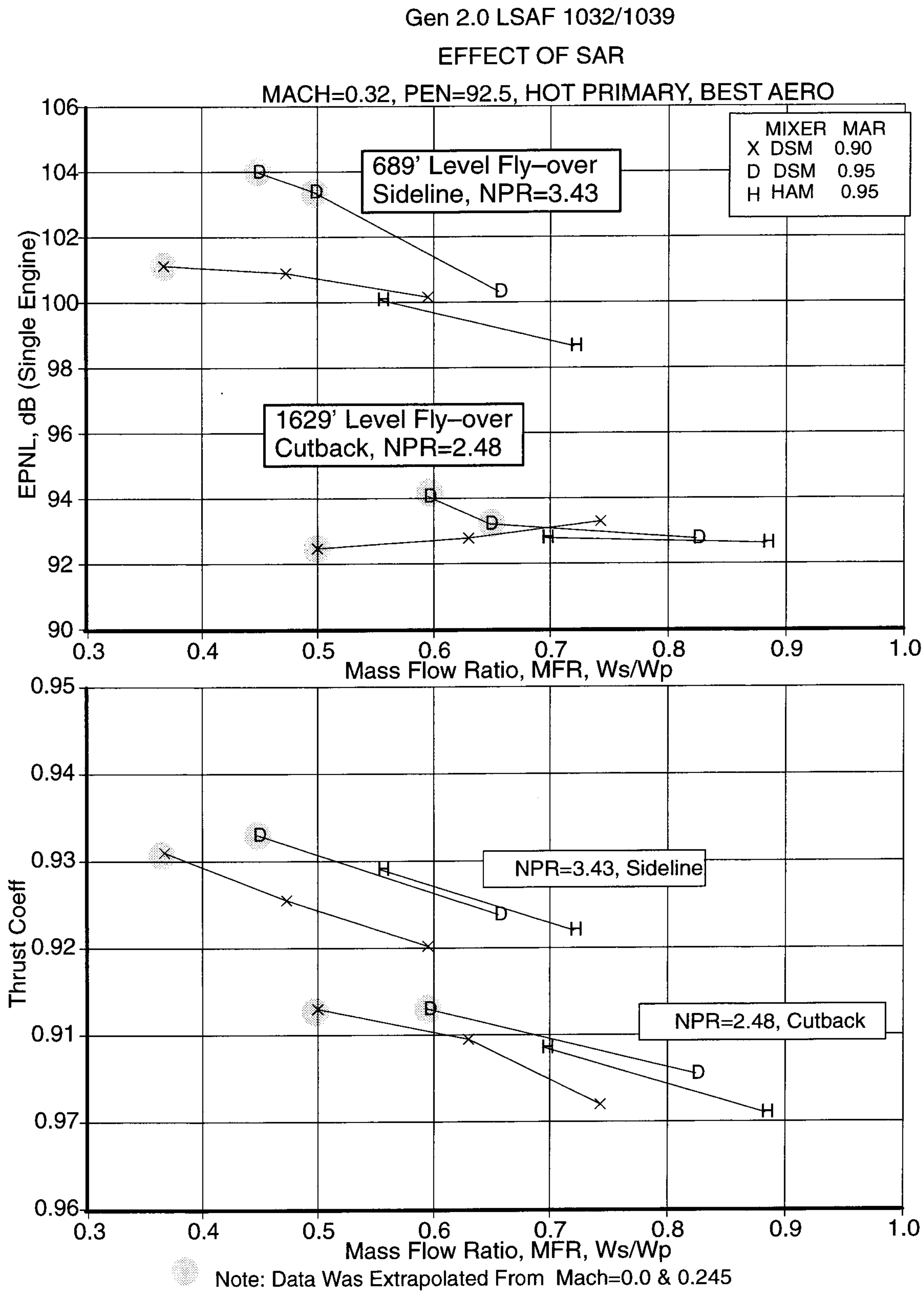


Figure 5.14, Effect of Mass Flow Ratio With Varying ASAR Mach=0.32, 13mm SiC, Hot Primary

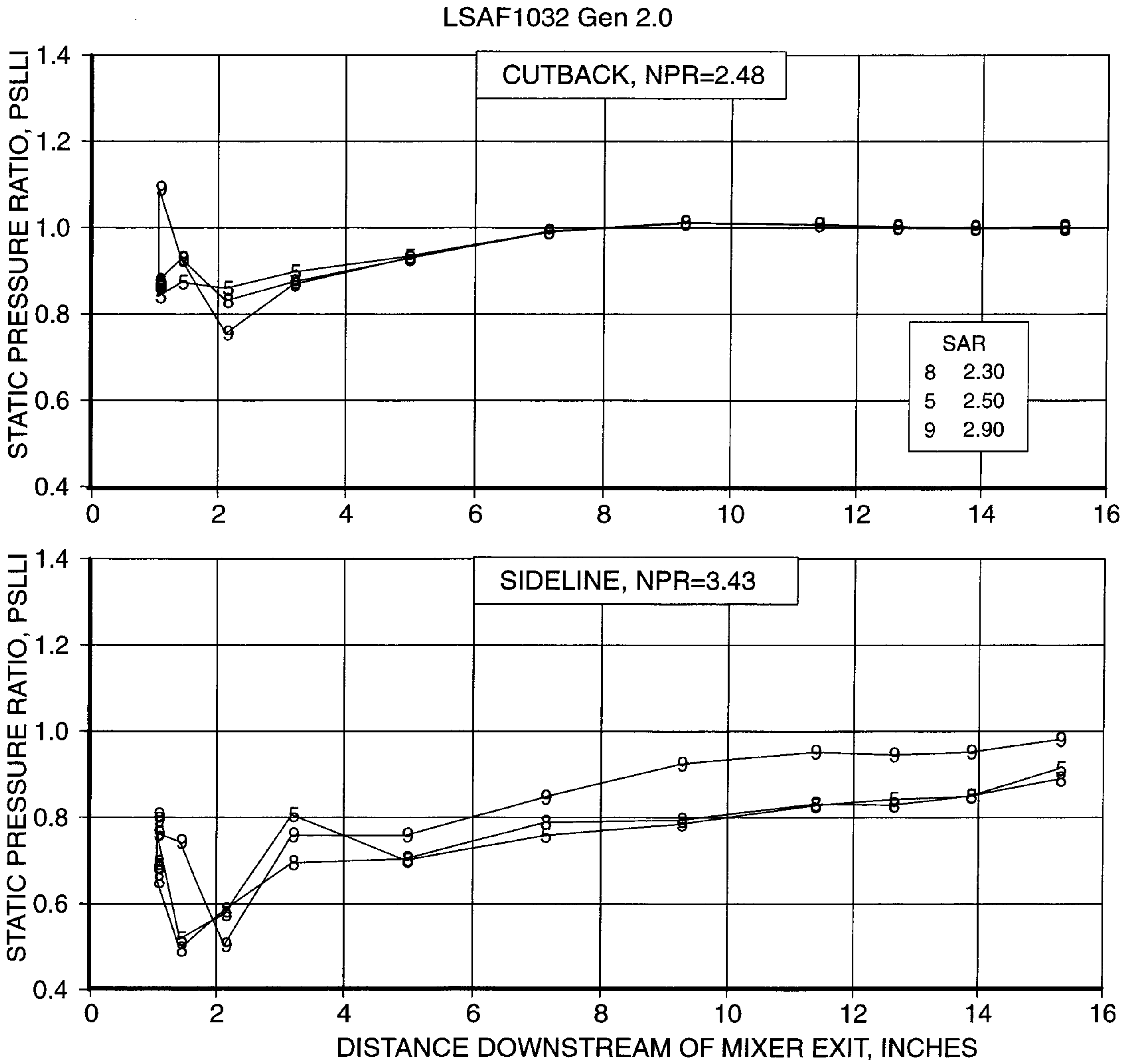


Figure 5.15, Effect of SAR on Duct Sidewall Statics, Mach=0.245, 13mm SiC, Hot Primary, MAR=0.95

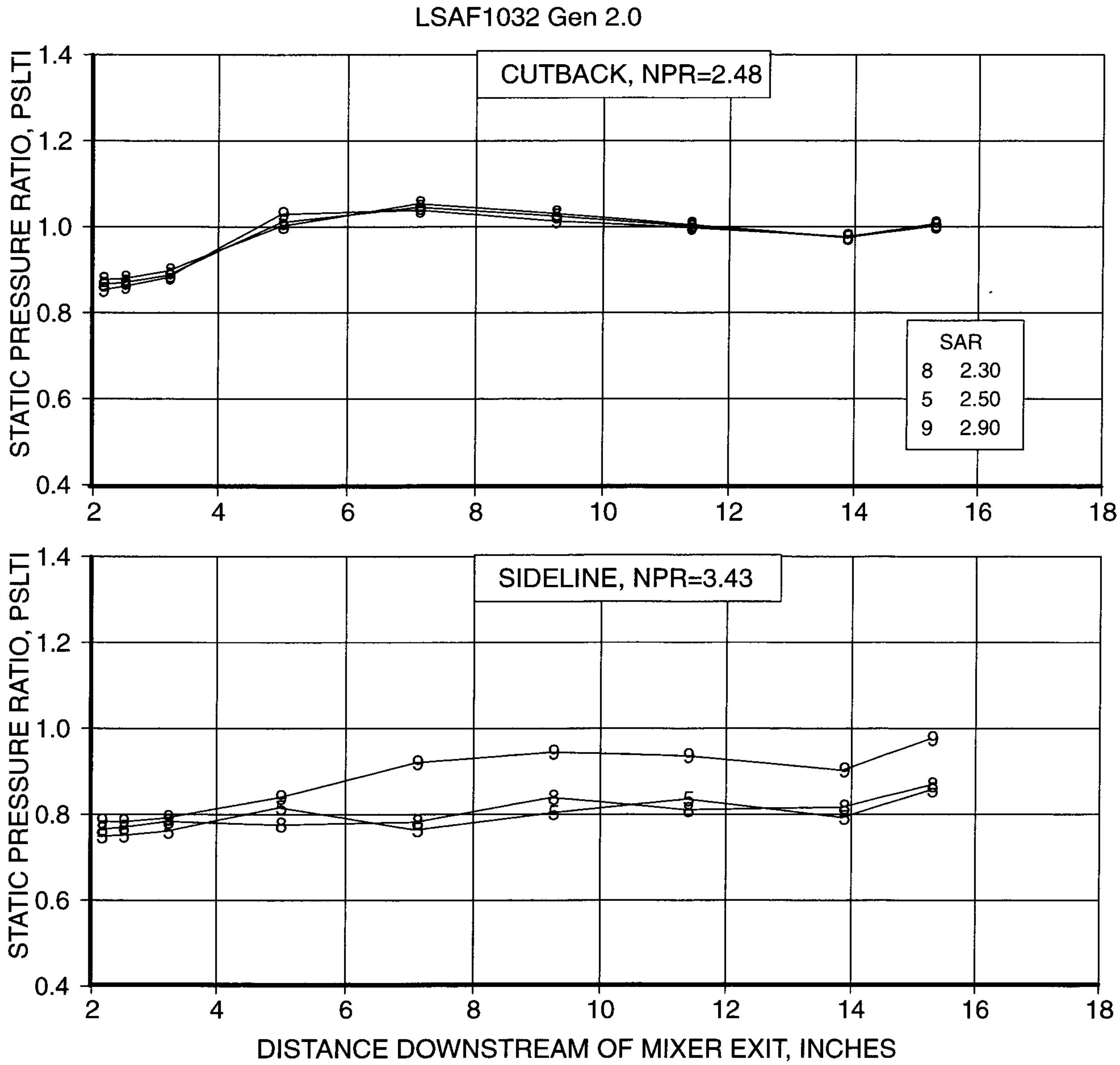


Figure 5.16, Effect of SAR on Duct Flap Statics, Mach=0.245, 13mm SiC, Hot Primary, MAR=0.95

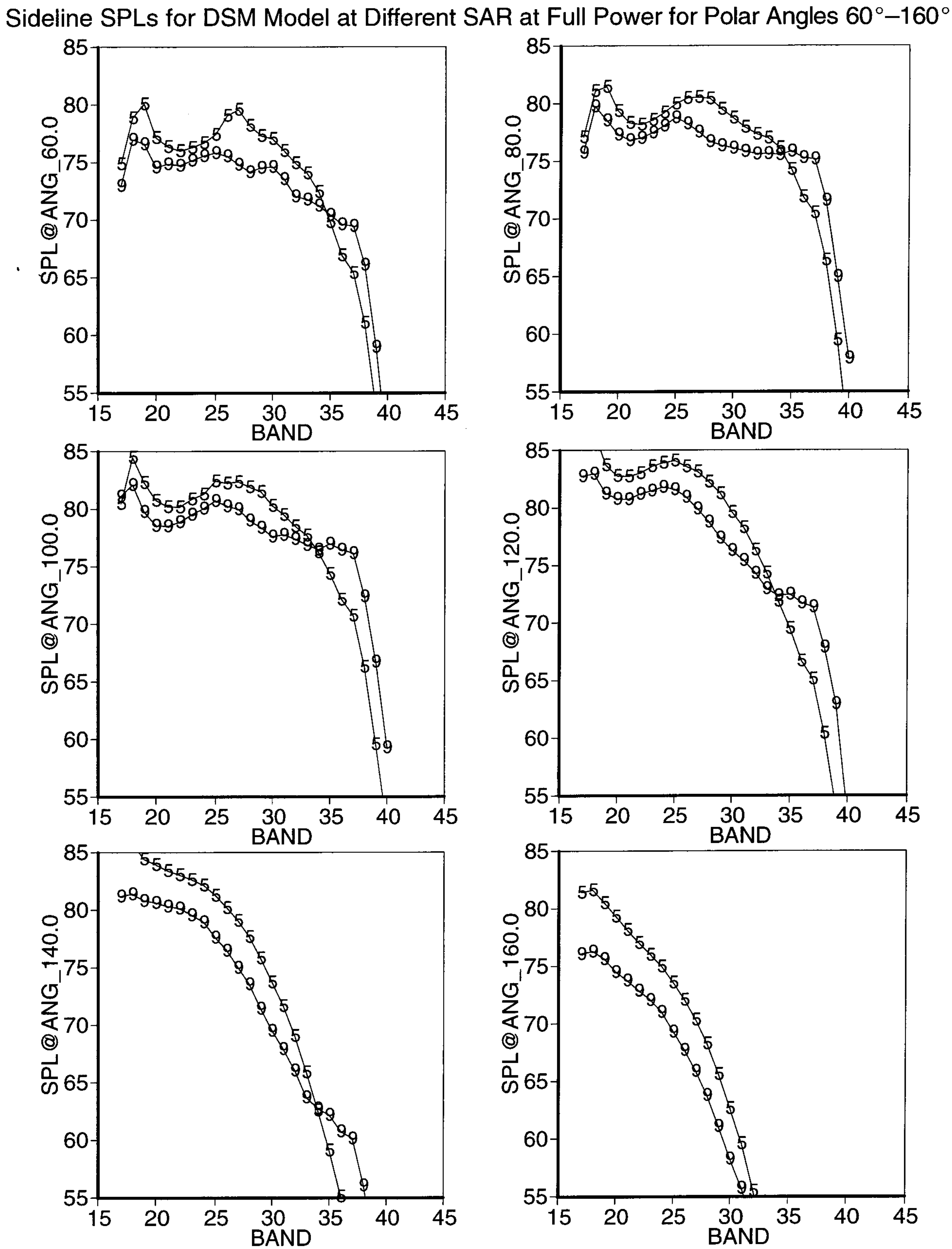


Figure 5.17, Effect of SAR on Extrapolated Spectra, DSM Model, 13mm SiC, SAR 2.5 (5) and SAR 2.9 (9) at NPR 3.43, Mach=0.32, MAR=0.90

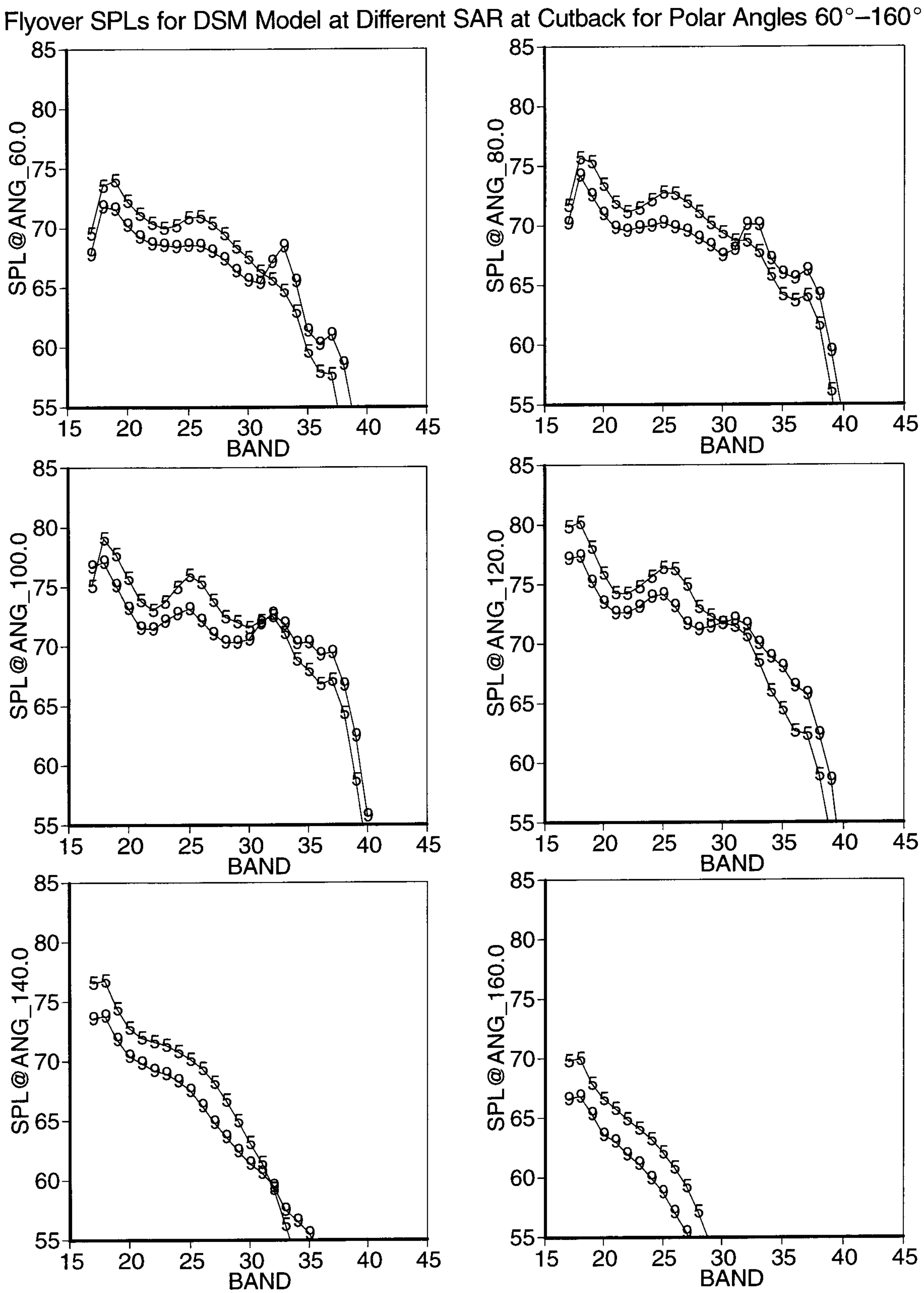


Figure 5.18, Effect of SAR on Extrapolated Spectra, DSM Model, 13mm SiC, SAR 2.5 (5) and SAR 2.9 (9) at NPR 2.48, Mach=0.32, MAR=0.90

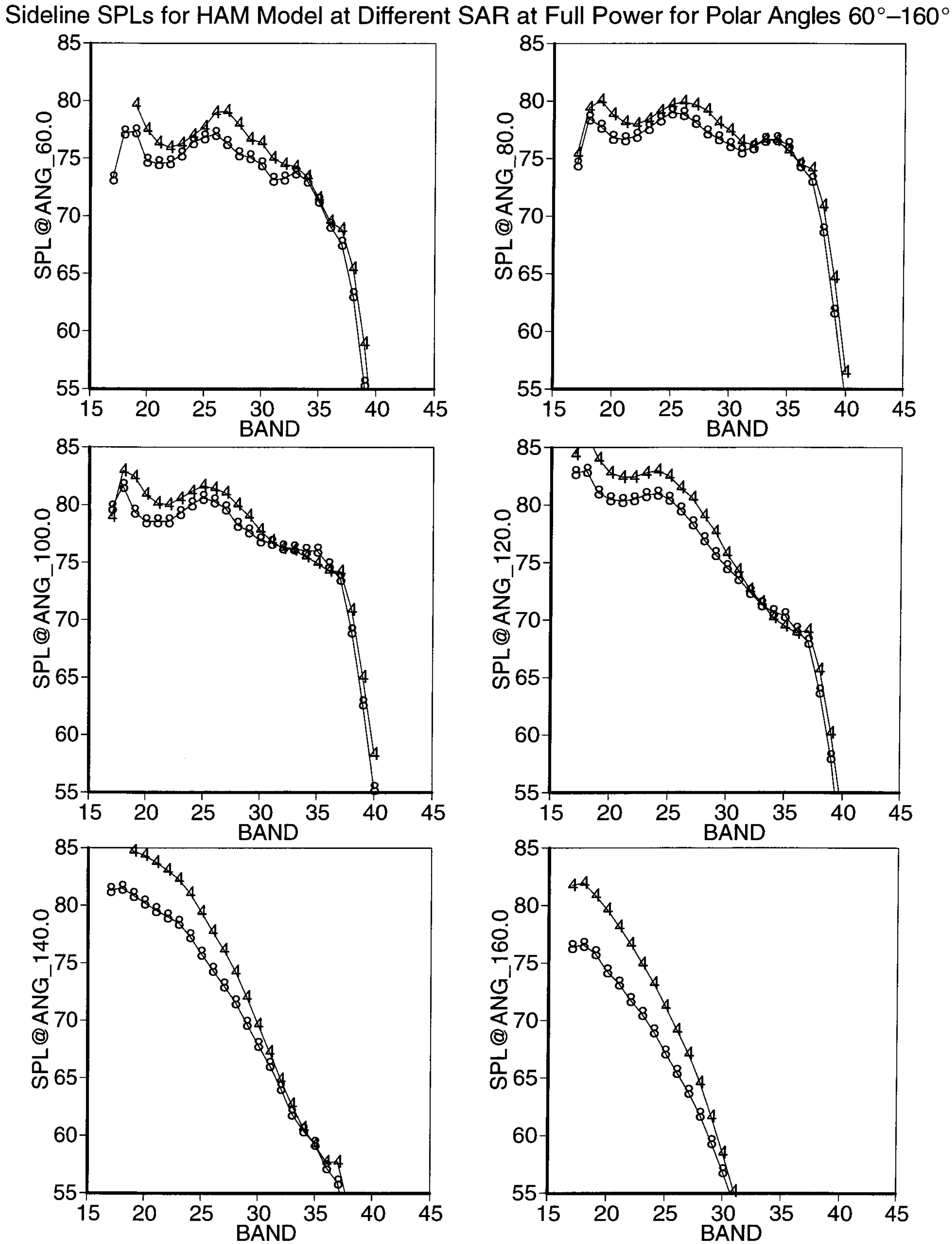


Figure 5.19, Effect of SAR on Extrapolated Spectra, HAM Model, 13mm SiC, SAR 2.5 (4) and SAR 2.9 (8) at NPR 3.43, Mach=0.32, MAR=0.95

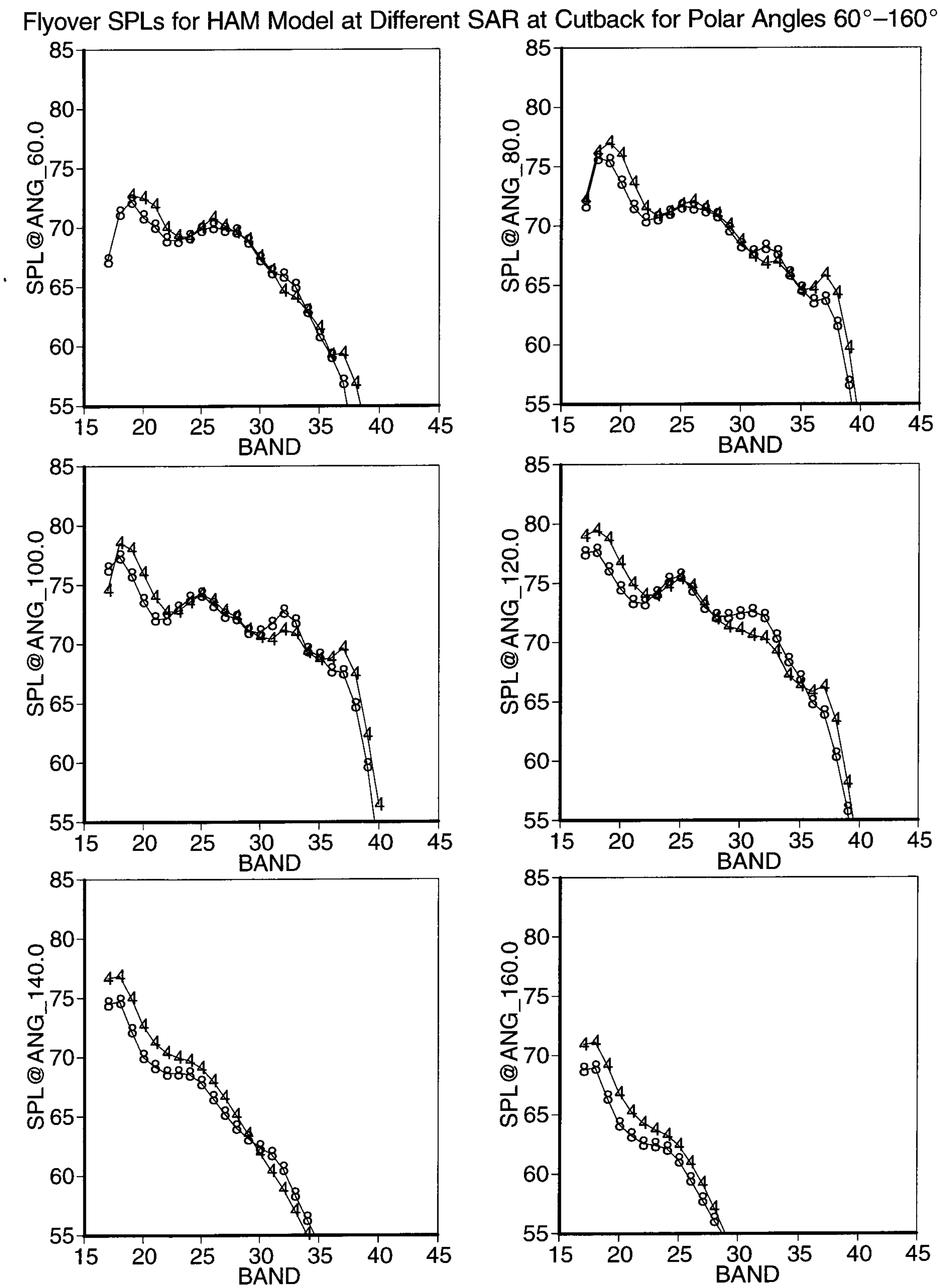


Figure 5.20, Effect of SAR on Extrapolated Spectra, HAM Model, 13mm SiC, SAR 2.5 (4) and SAR 2.9 (8) at NPR 2.48, Mach=0.32, MAR=0.95

5.4 Effect of Penetration

The effect of penetration (mixer chute height as percentage of mixing duct height) on the HAM best aero mixers at the cutback and sideline conditions is shown in Figure 5.21. As penetration increases, the noise and thrust both fall. At sideline, the effect of penetration is ~–0.15 EPNdB/PEN% and ~–0.22 CFN%/PEN%. The corrected mass flow ratio peaks near 92.5%, suggesting a compromise optimum penetration between aero and acoustics of about 92.5%.

Figure 5.22 shows the static pressures along the sidewall for cutback and sideline conditions for each of the penetrations tested with the DSM. The static pressures are not affected by penetration.

Figure 5.23 shows the effect of penetration on the extrapolated noise spectra at sideline at the full power point for the HAM model (mixers 3, 4, and 10). The effect of increasing PEN from 85% to 92.5% is to decrease the low frequency noise due to the mixed jet in the aft arc (lower plots) and reduce the mid frequency noise in the forward arc. When penetration is increased from 92.5% to 100% only the aft arc low frequency benefit is realized.

Figure 5.24 shows the effect of penetration on the extrapolated noise spectra at cutback at the flyover point for the HAM model (mixers 3, 4, and 10). Increasing PEN from 85% to 92.5% decreases the low and mid frequency noise as with sideline. However, when penetration is increased from 92.5% to 100% little or no low frequency benefit is realized.

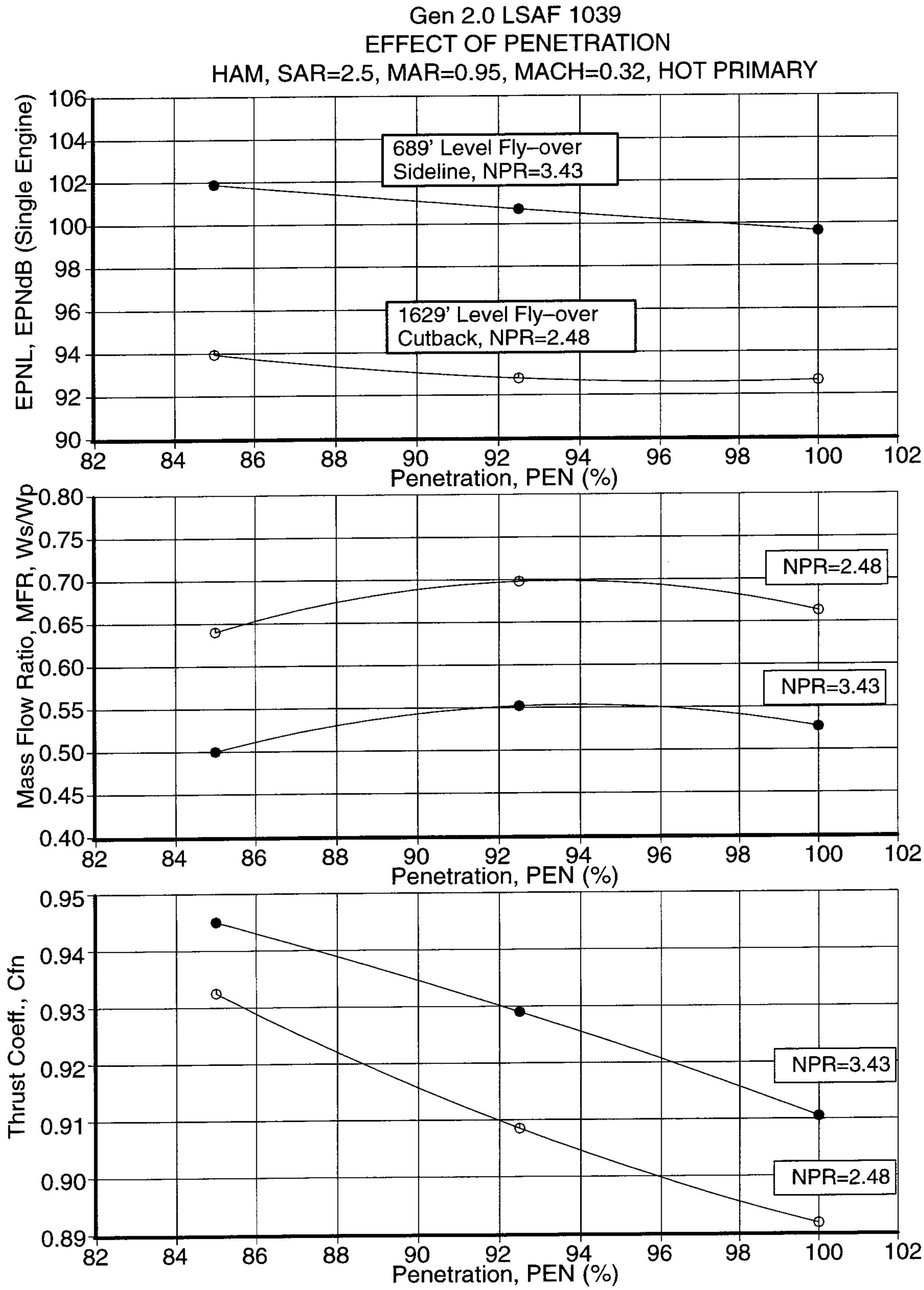


Figure 5.21, Effect of Penetration, Mach=0.32, 13mm SiC, Hot Primary

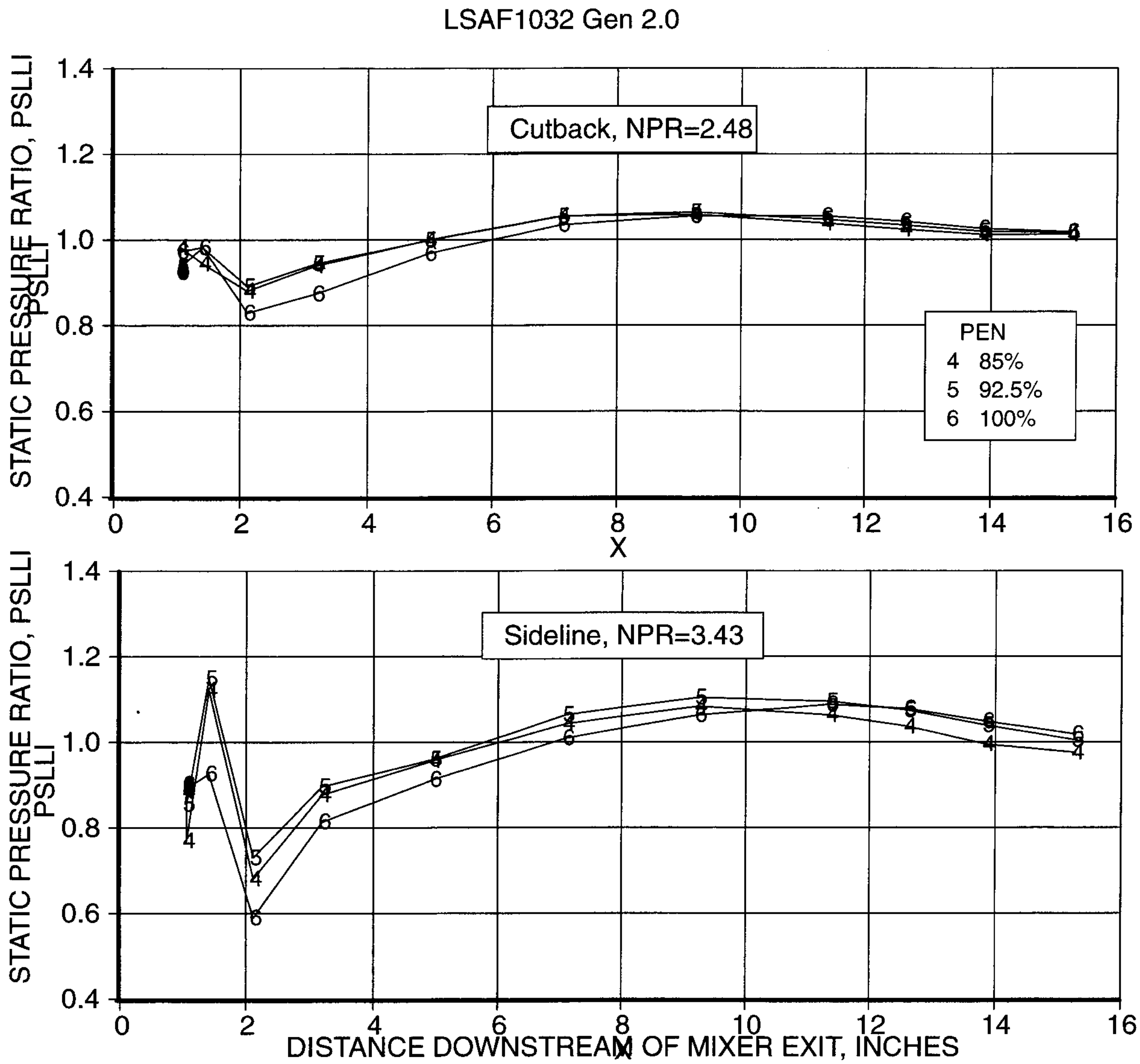


Figure 5.22, Effect of Penetration, DSM, Mach=0.32, MAR=0.90, 13mm SiC,

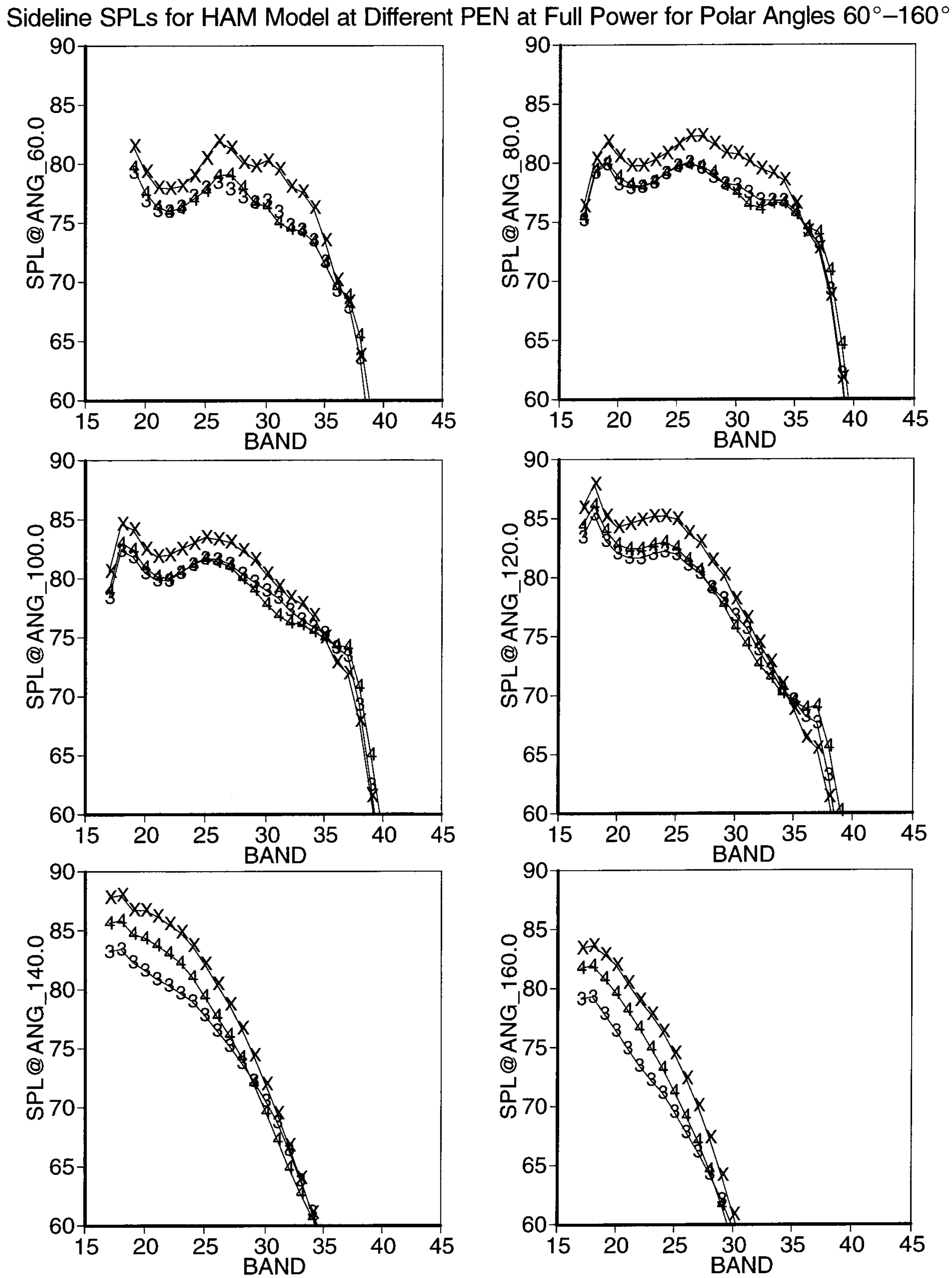


Figure 5.23, Effect of PEN on Extrapolated Spectra, HAM Model, 13mm SiC, PEN 100% (3), 92.5% (4), and 85% (X) at NPR 3.43, Mach=0.32, MAR=0.95

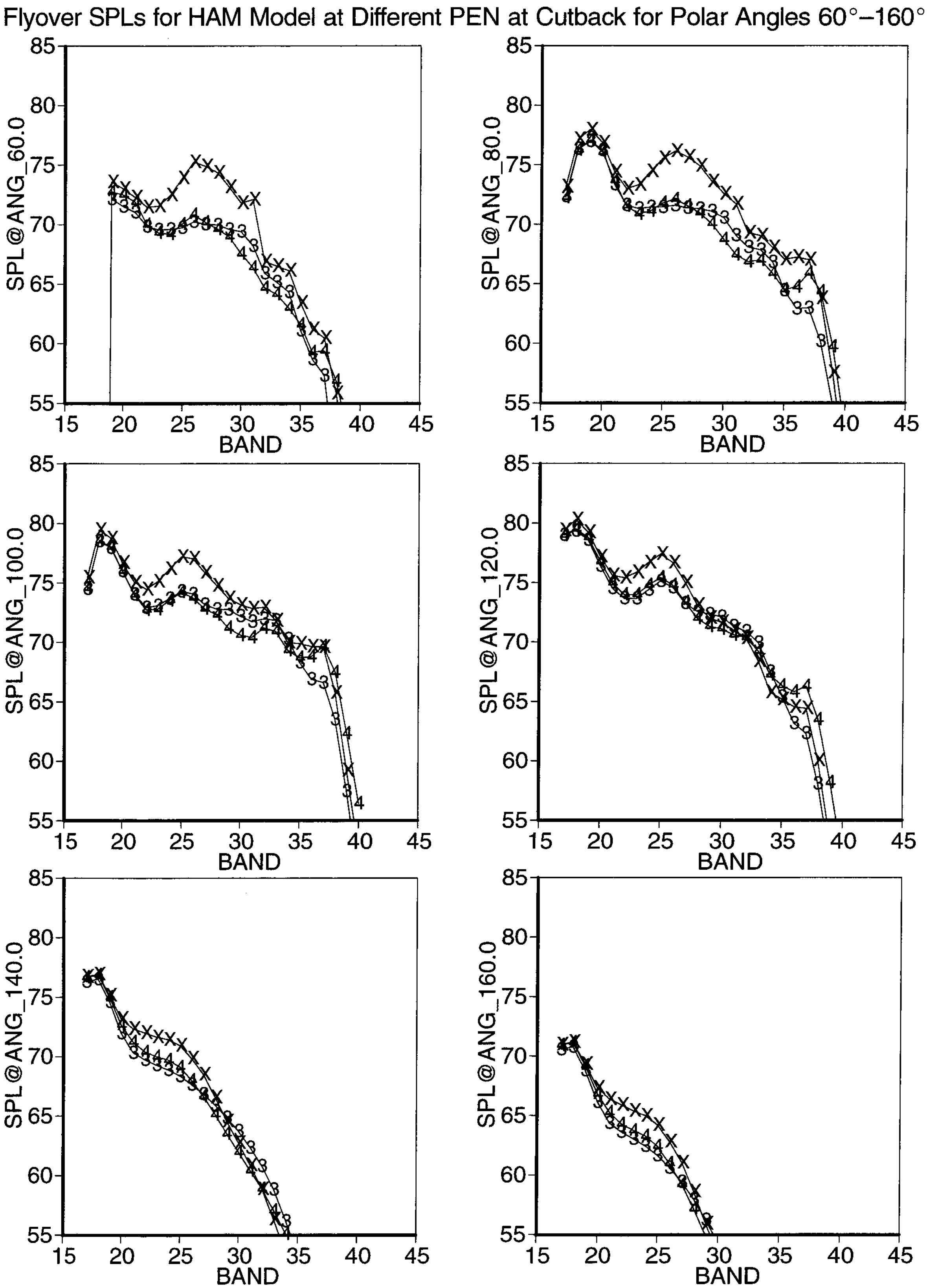


Figure 5.24, Effect of PEN on Extrapolated Spectra, HAM Model, 13mm SiC, PEN 100% (3), 92.5% (4), and 85% (X) at NPR 2.48, Mach=0.32, MAR=0.95

5.5 Effect of MAR

Figure 5.25 shows the effect of MAR on the performance of DSM mixer 9 at Mach=0.32. For the cutback design condition both the noise and the thrust performance are optimized at around MAR=0.95. At the sideline condition, the optimum MAR is less obvious. The performance is still peaking around MAR=0.95, but the noise is increasing slightly from MAR=0.90 to 0.95. This suggests an optimum noise/thrust trade somewhere between MAR=0.90 and 0.95. Aspiration also increases with MAR. The trend with the DSM model is the optimum noise/thrust trade point for MAR was closer to MAR=0.90 at the lower SAR values, SAR=2.3 and 2.5, but closer to MAR=0.95 at SAR=2.9.

Figure 5.26 shows the effect of MAR on the mixing duct sidewall centerline static pressures for the cutback and sideline design conditions (hot primary flow and a tunnel speed of Mach 0.32). At cutback power MAR has little effect. At sideline, MAR=0.90 is subsonic through most of the mixing duct and the MAR=1.00 is supersonic through the length of the mixing duct. MAR=0.95 lies between – initially in supersonic mode transitioning to subsonic about halfway down the duct.

Figure 5.27 shows the effect of MAR on the extrapolated noise spectra at sideline at the full power point for DSM mixer 9. The effect of increasing MAR is to increase the high frequency mixing noise and the mid frequency noise in the forward arc. When MAR is increased to 1.00 the noise increase covers more bands and polar angles.

Figure 5.28 shows the effect of MAR on the extrapolated noise spectra at cutback at the flyover point for DSM mixer 9. Increasing MAR from 0.90 to 0.95 at cutback power has little effect on noise. But when MAR is increased to 1.00 the noise is generally worse.

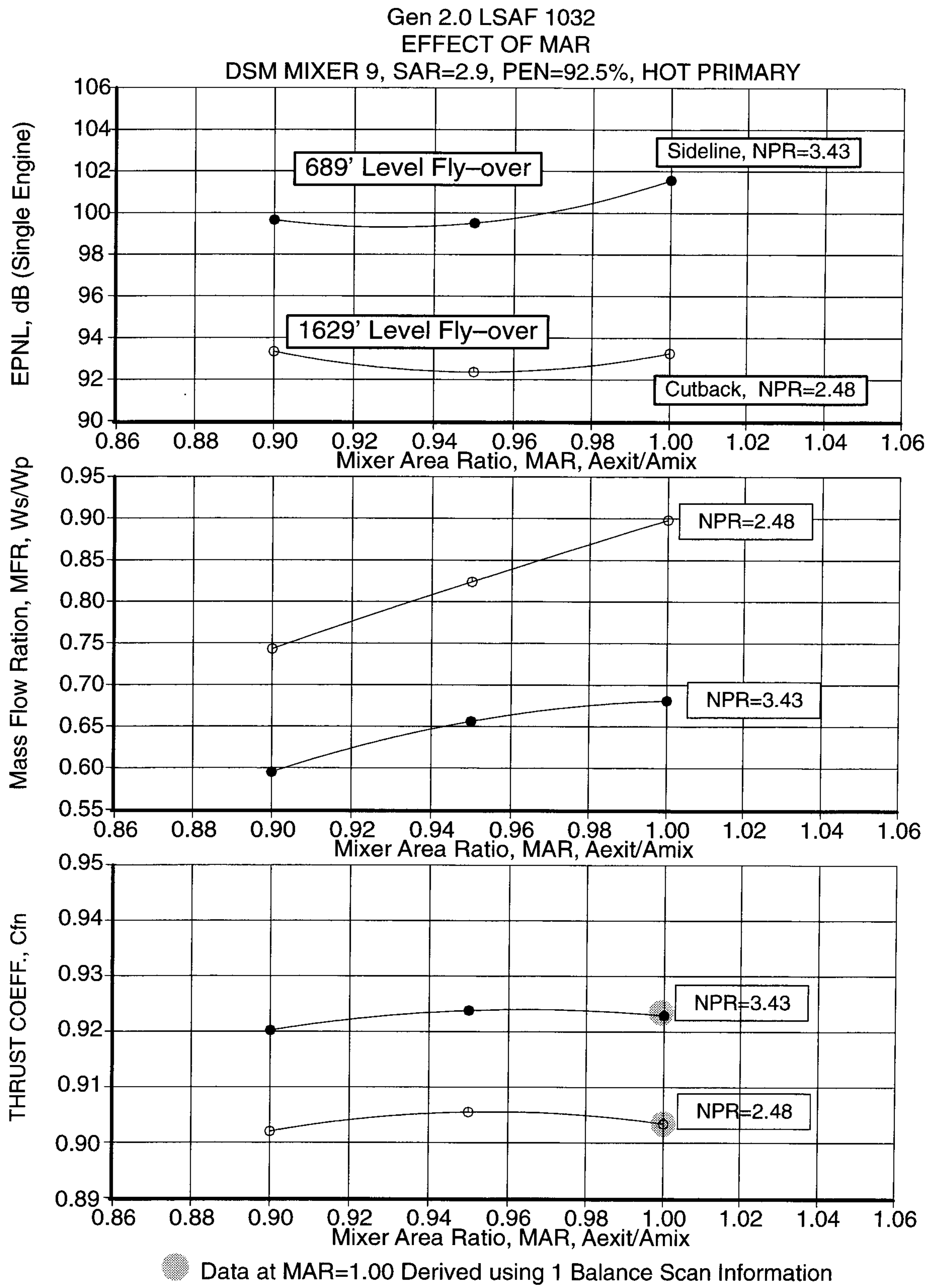


Figure 5.25, Effect of MAR on Mixer 9, Mach=0.32, 13mm SiC, Hot Primary

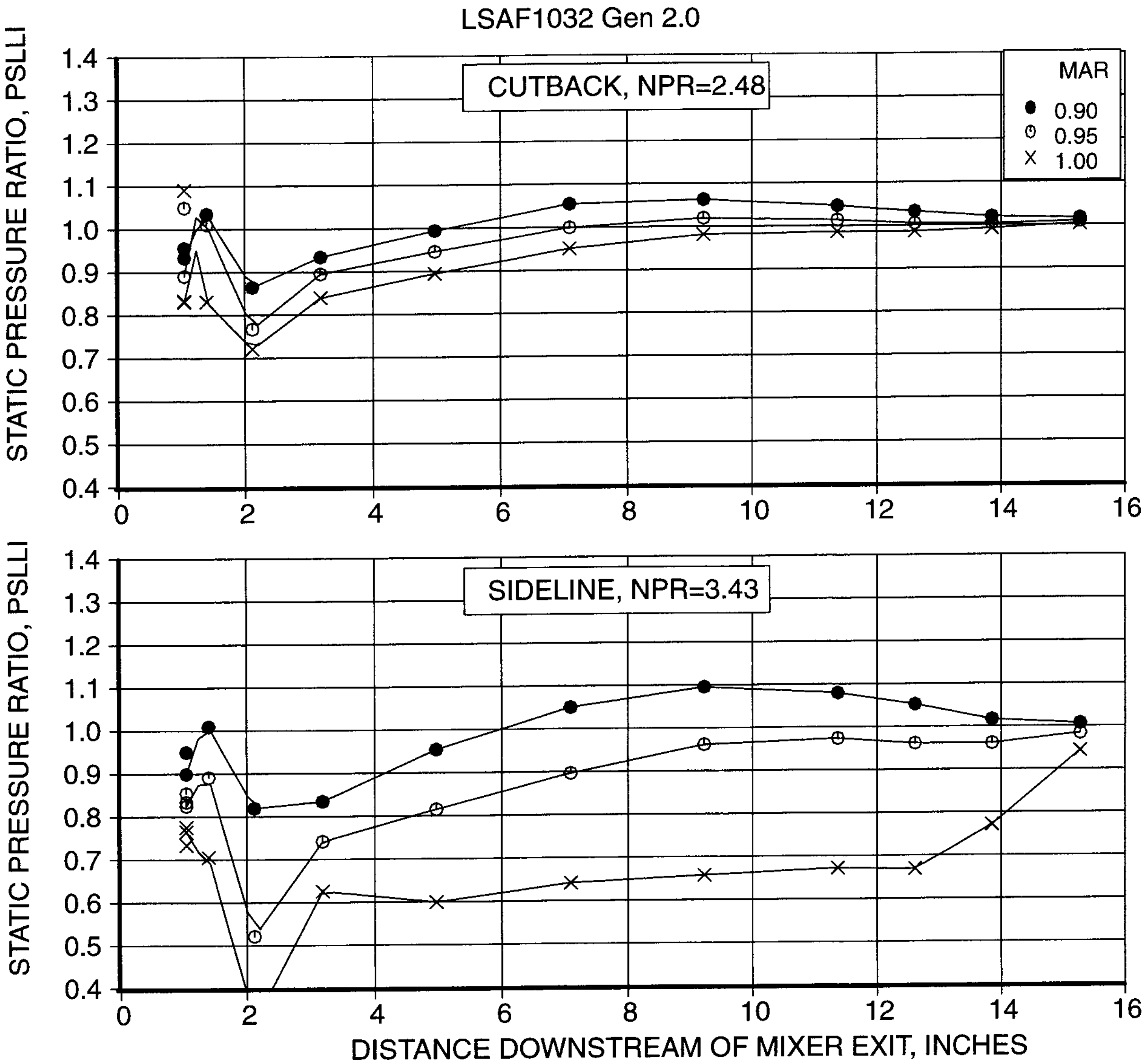


Figure 5.26, Effect of MAR, DSM Mixer 9, Mach=0.32, SAR=2.9, 13mm SiC,

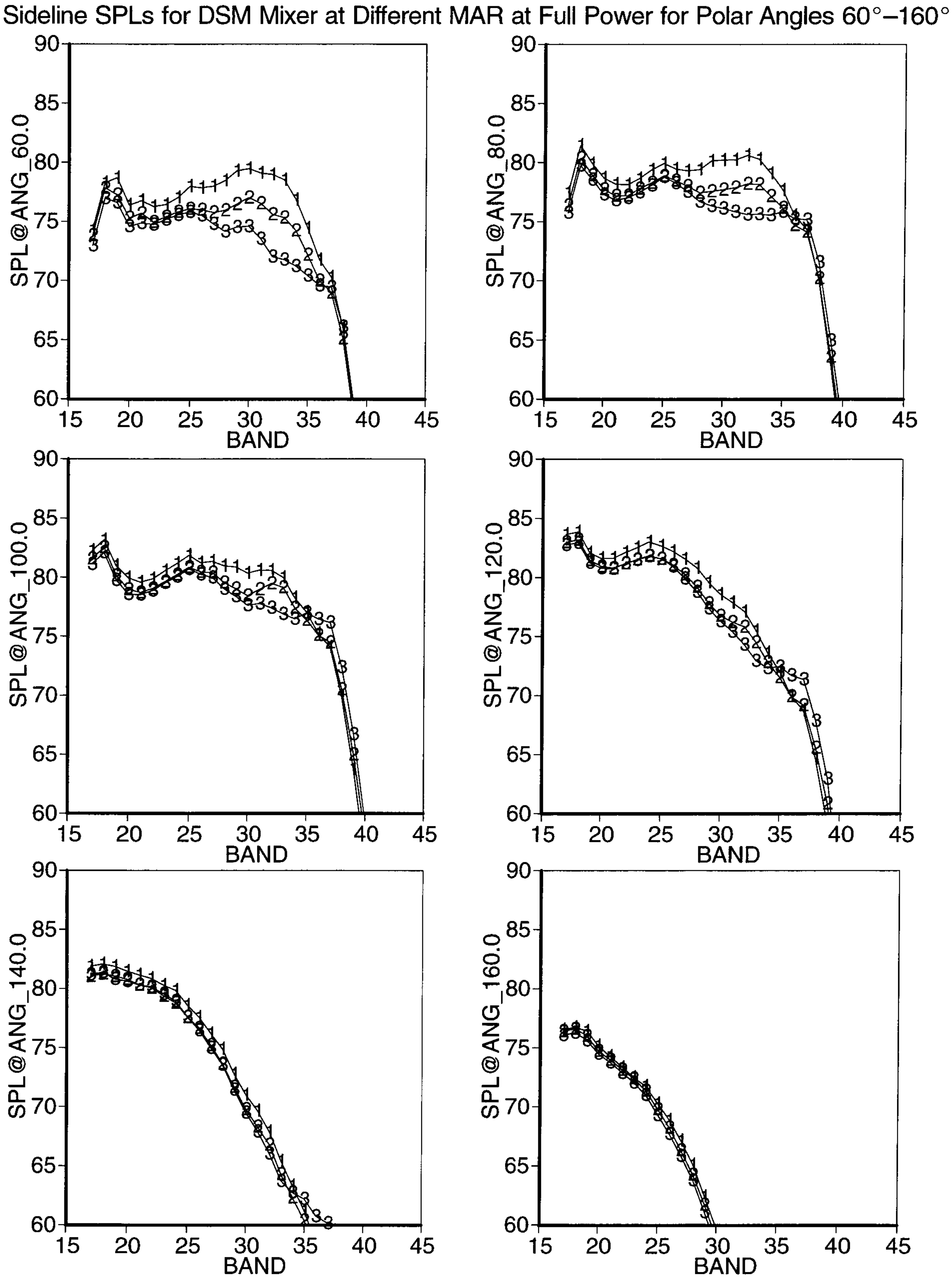


Figure 5.27, Effect of MAR on Extrapolated Spectra, DSM Model, 13mm SiC, MAR 1.00 (1), 0.95 (2), and 0.90 (3) at NPR 3.43, Mach=0.32, SAR=2.9

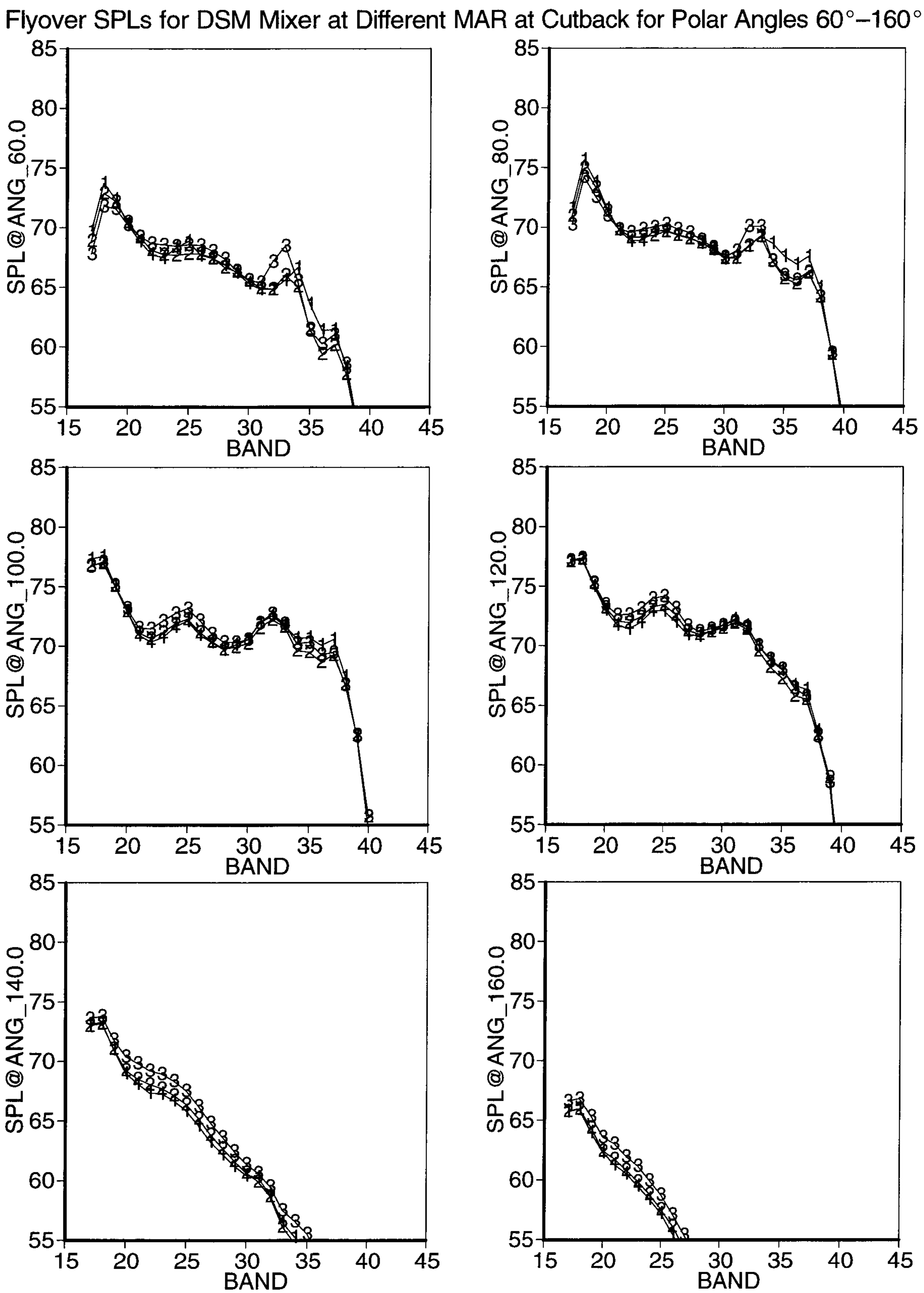


Figure 5.28, Effect of MAR on Extrapolated Spectra, DSM Model, 13mm SiC, MAR 1.00 (1), 0.95 (2), and 0.90 (3) at NPR 2.48, Mach=0.32, SAR=2.9

5.6 Effect of Flap Length

The effect of changing the HAM mixing duct length from ~120" full scale to ~160" full scale is shown in Figure 5.29. The additional 40" full scale (about 5.7" model scale) of untreated duct is added just downstream of the mixer chute exit. For cutback power the longer duct causes a thrust loss of 0.77% with a noise reduction of 1.29 EPNdB. At sideline power the thrust loss is greater, 1.21%, but the noise reduction is also better at 2.37 EPNdB. This works out to a noise/thrust trade of 1.67 ΔEPNdB/ΔCFN(%) at cutback and 1.96 ΔEPNdB/ΔCFN(%) at sideline. The flap length does not strongly impact the nozzle aspriation.

Figure 5.30 shows comparison of the static pressure in the mixing duct between the long and short mixing ducts. Both flap lengths show the flow is in subsonic mode at both cutback and sideline conditions with static pressure in the mixing duct higher than ambient through much of its length.

Figure 5.31 shows the effect of flap length on the extrapolated noise spectra at sideline at the full power point for HAM mixer 8. There is a marked noise reduction of the high frequency mixing noise with the longer ejector. The dotted lined spectra show that even for the hardwall ejector, there is some noise reduction simply due to the increased ejector length. Similar behavior is seen with the extension at cutback power as shown in figure 5.32.

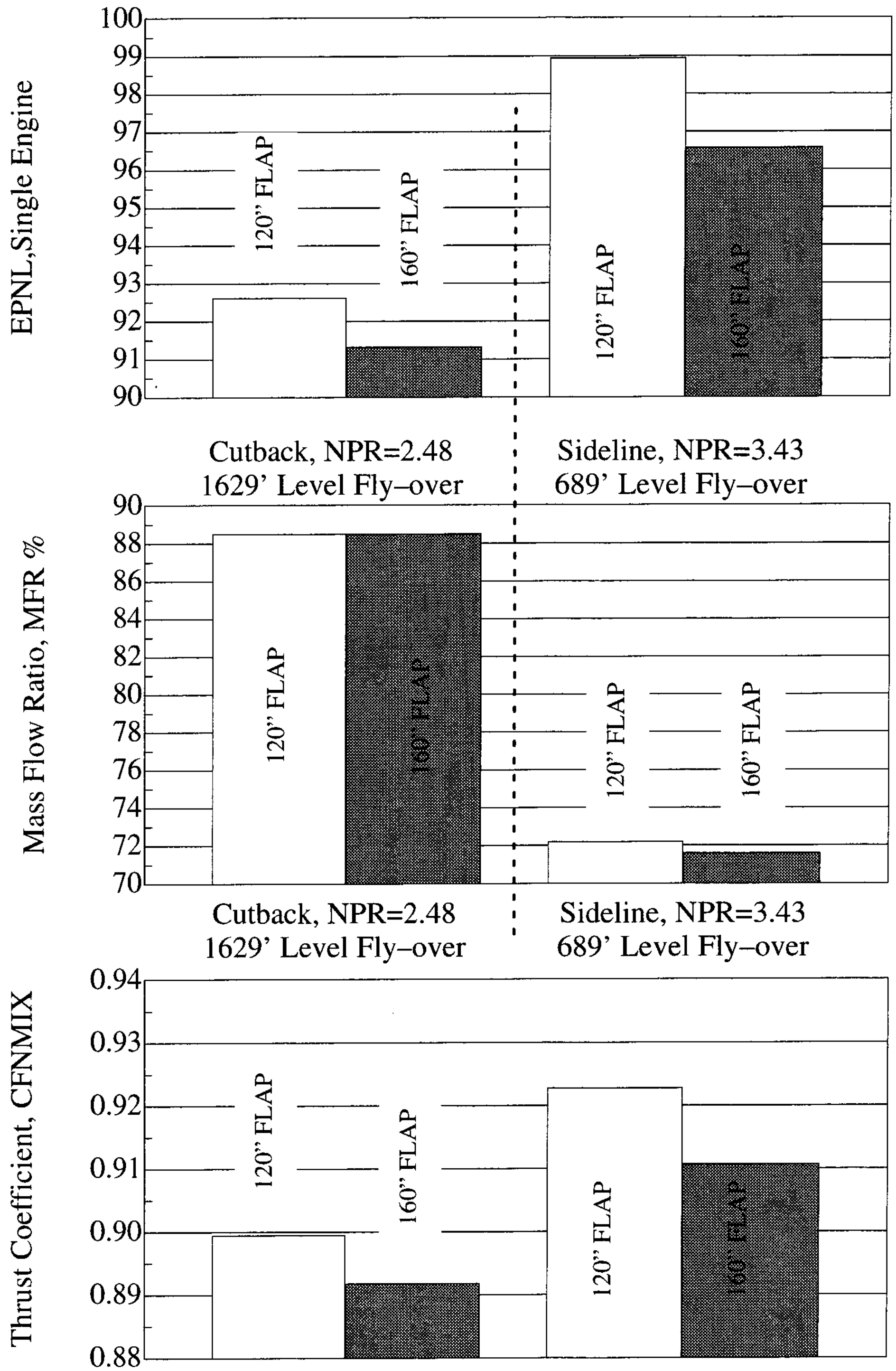


Figure 5.29, Effect of Flap Length, HAM Mixer 8, SAR=2.9, MAR=.95, Mach=0.32, Hot Primary

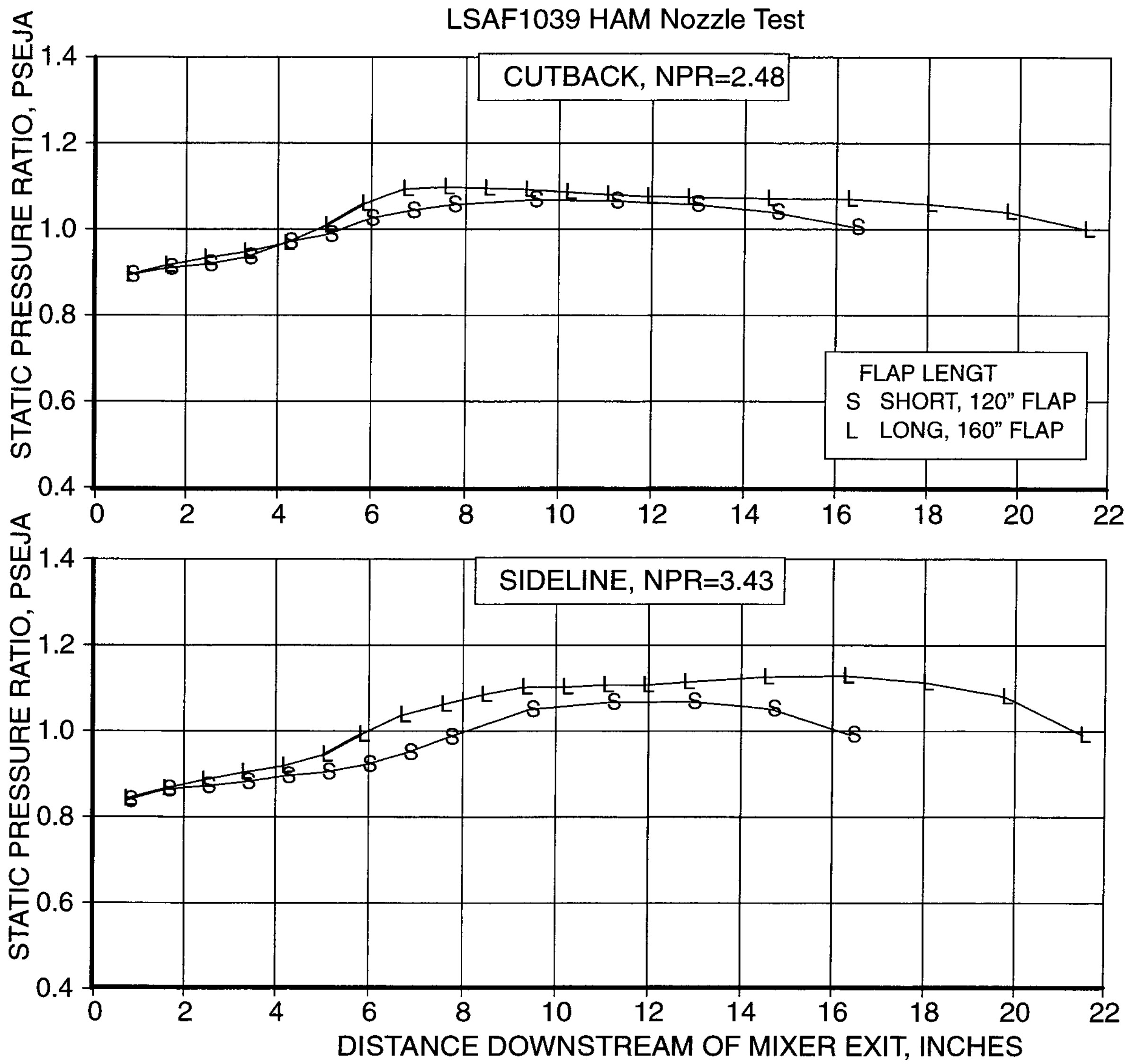


Figure 5.30, Effect of Mixing Duct Length, HAM Mixer 8, Mach=0.32, MAR=0.95, 13mm SiC,

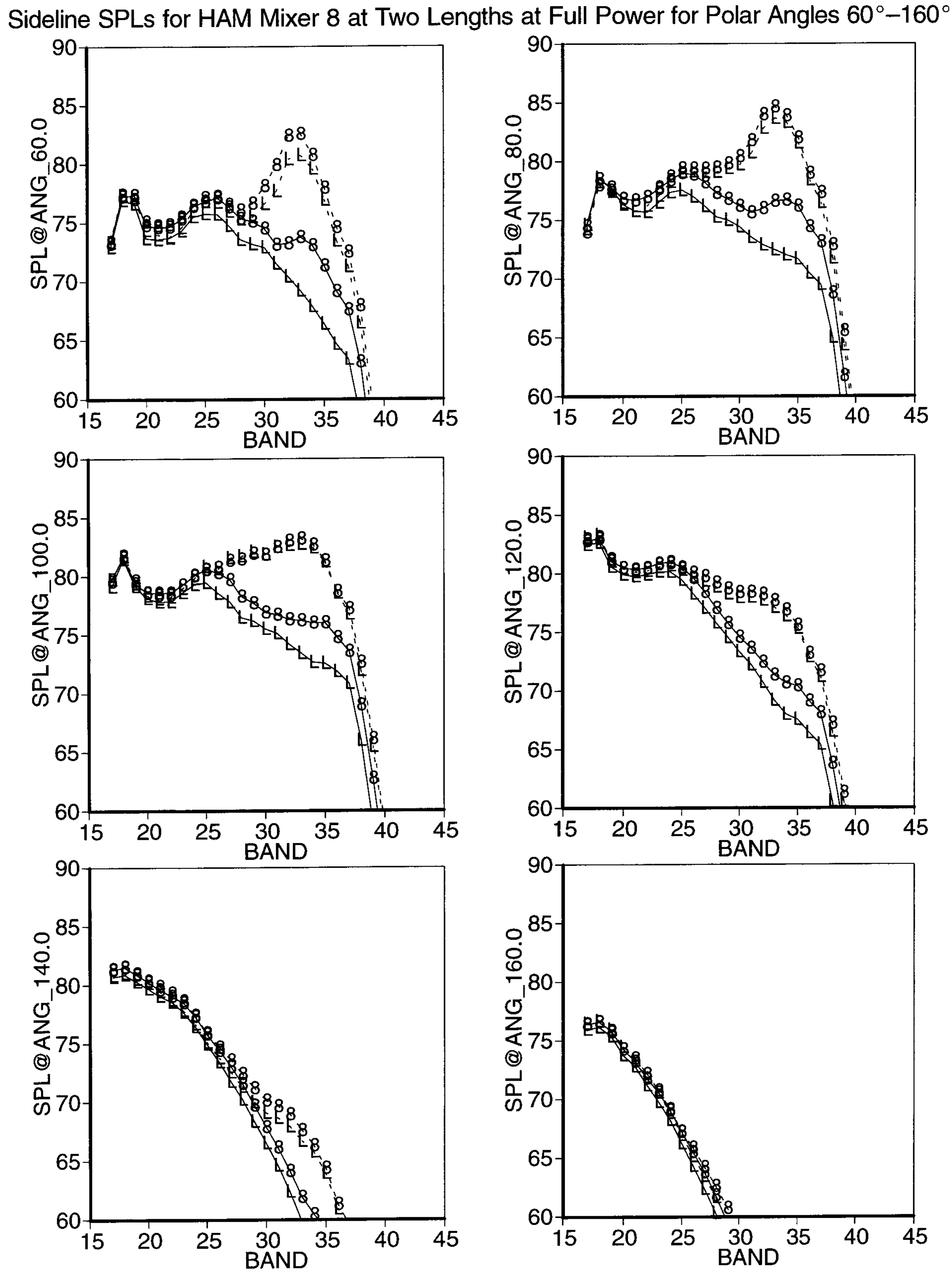


Figure 5.31, Effect of Length on Extrapolated Spectra, HAM Model, SAR=2.9, MAR 0.95, 120" (8) and 160" (L) with 13mm SiC (solid) and HW (dotted), at NPR 3.43, Mach=0.32

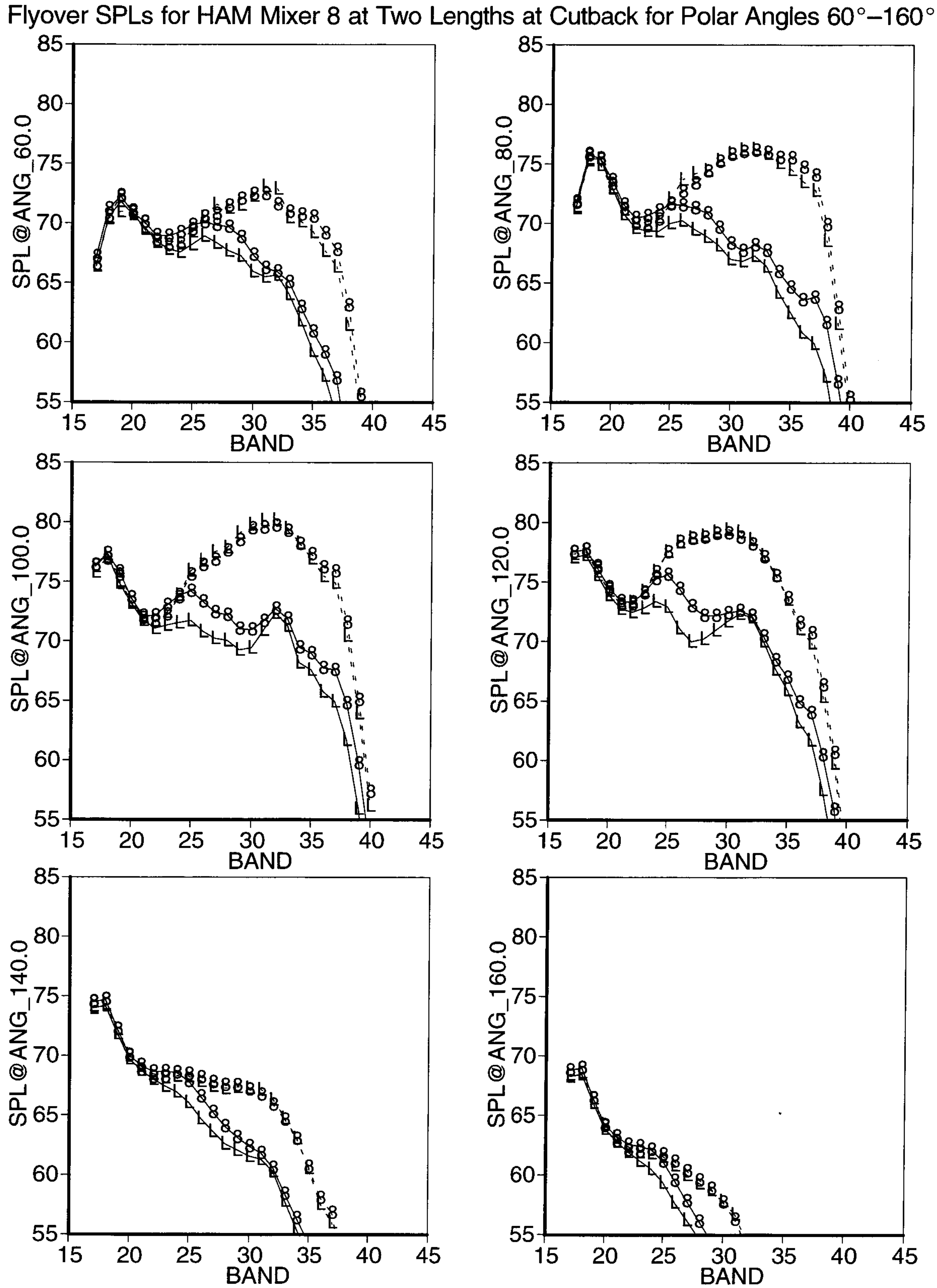


Figure 5.32, Effect of Length on Extrapolated Spectra, HAM Model, SAR=2.9, MAR 0.95, 120” (8) and 160” (L) with 13mm SiC (solid) and HW (dotted), at NPR 2.48, Mach=0.32

5.7 Effect of Liners

Figure 5.33 illustrates the effect of the various liner configurations tested with the DSM: smooth hardwall, felt metal over 7mm "single–degree–of–freedom" (SDOF) honeycomb, perf plate over 13 mm SDOF (large cubic cells), and perf plate over 13mm SiC. The felt metal face sheet used in the one 7mm configuration provides some scaling effects of the thrust/pumping performance. It was not practical to scale the hole sizes on the full scale liner face sheet to model scale. The resultant model scale liner face sheet with a practical hole size has holes far to big relative to the full scale liner. This introduces a liner thrust loss on the model not representative of the full scale nozzle. The smooth surface of the felt metal represents a model liner surface that is representative of the full scale liner. The thrust performance of the felt metal face liner approaches the hardwall liner performance and is about 2% better than the porous tray liners. This suggests that the full scale porous tray liners should expect a thrust performance improvement over the model scale porous tray liners of about 2% due to large hole size of the model liner. The 13mm SiC liner provided the best acoustic performance. At cutback the improvement is very noticeable with a 6 EPNdB reduction in noise over the hardwall and better than a 2 EPNdB improvement over either thickness of the SDOF liner. At sideline the 13mm Sic provides a reduction of about 2.5 EPNdB over the hardwall and about 1 EPNdB over the SDOF liners. Except for the 13mm SDOF liner, the aspiration does not vary much between the different liners.

Figure 5.34 illustrates the effect of 3 liner configurations tested with the HAM, smooth hardwall, simulated hardwall, and 13mm SiC with perf face sheet. The simulated hardwall used 2mil thick sheet metal strips behind the perf face sheet blocking the foam metal bulk absorber. The thrust performance of the simulated hardwall was about 1% better than the 13mm SiC configuration – suggesting that flow within the bulk absorber is causing additional thrust loss. The thrust performance of the smooth hardwall is about 1 to 1.5% better than the simulated hardwall. Acoustically, the simulated hardwall provided some noise reduction, about 2 EPNdB at cutback and 0.8 EPNdB at sideline. The 13mm SiC liner provided even better acoustic performance for the HAM than the DSM – with a reduction of about 6 EPNdB at cutback and 4 EPNdB at sideline. The variation in aspiration for the different HAM liners is also shown in the figure. The hardwall configuration provides the best pumping. However, the treated porous tray configuration provides slightly better pumping performance than the simulated hardwall.

Figure 5.35 shows the static pressure distribution down the DSM mixer duct for the hardwall, 7mm SDOF, and 13mm SiC liners. In the hardwall configuration the mixing duct flow is supersonic. In the 7mm SDOF (felt metal) the mixing duct flow remains supersonic to near the end of the duct. For the 13mm SiC (perf plate) the mixing duct flow is initially supersonic but transitions to subsonic by mid–duct. The transition to subsonic mode in the mixing duct occurs sooner with lossier liners.

Figure 5.36 shows the effect of different treatments on the extrapolated noise spectra at sideline at the full power point for DSM mixer 9. As expected, the different treatments all reduce the high frequency mixing noise. The 13mm SiC foam bulk absorber had the highest noise reduction. The 7mm SDOF honeycomb with felt metal face sheet reduced the noise about half as well. And the spectra of the 13mm SDOF with perf plate face sheet seems to oscillate between the two. At cutback power the behavior of the liners is similar, except the mixing noise reduced is higher (Figure 5.37).

Figure 5.38 shows the effect of different "hardwall" treatments on the extrapolated noise spectra at sideline at the full power point for HAM mixer 8. The simulated hardwall with the 2mil thick sheets under the perf sheet shows high frequency noise reduction relative to the "true" smooth

hardwall trays. Figure 5.39 shows similar behavior at cutback, and even shows lower mid frequency noise than the nozzle treated with 13mm SiC foam bulk absorber shown for comparison.

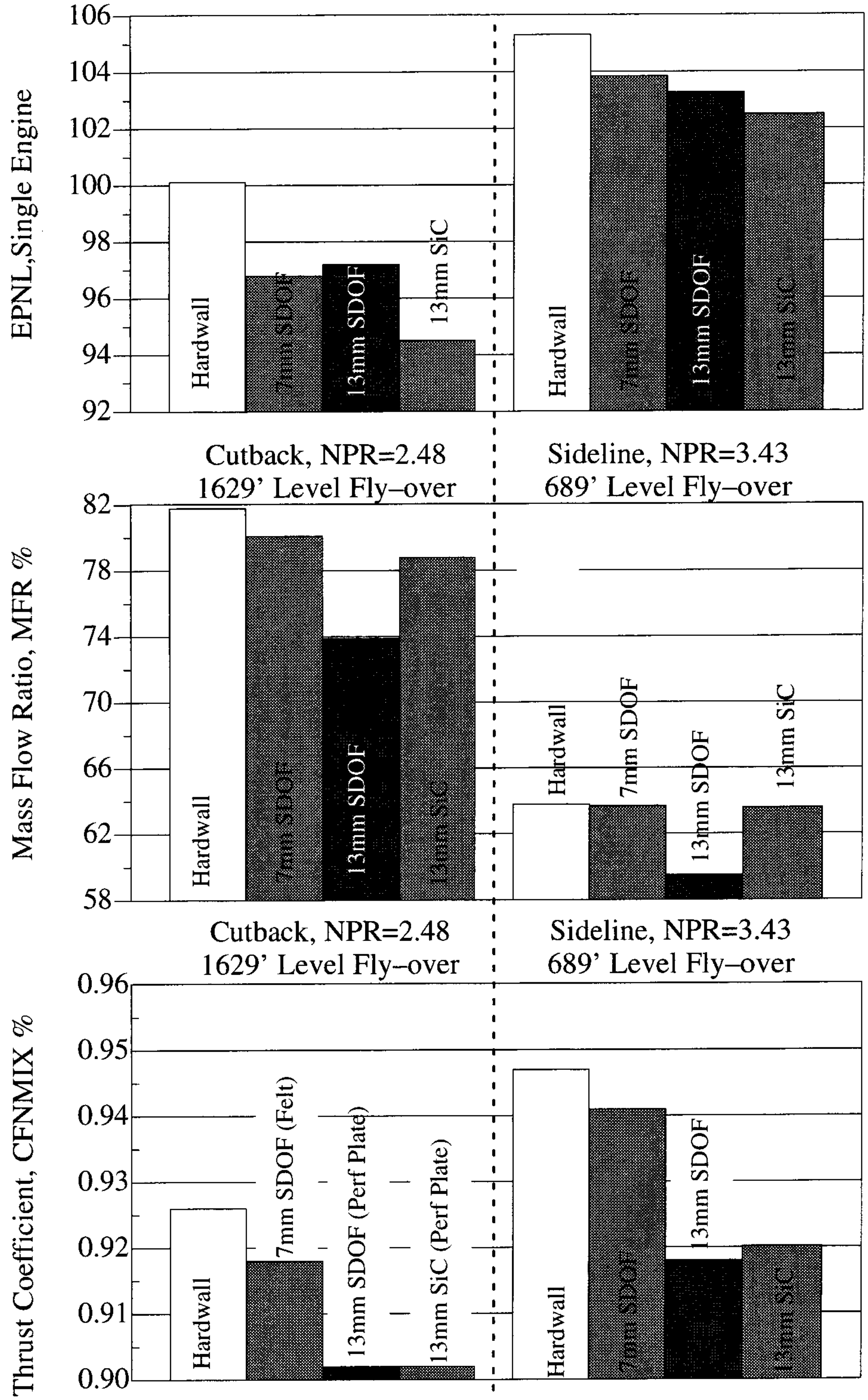


Figure 5.33, Effect of Liner on DSM Mixer 9, SAR=2.9, Mach=0.245, MAR=0.95 Hot Primary

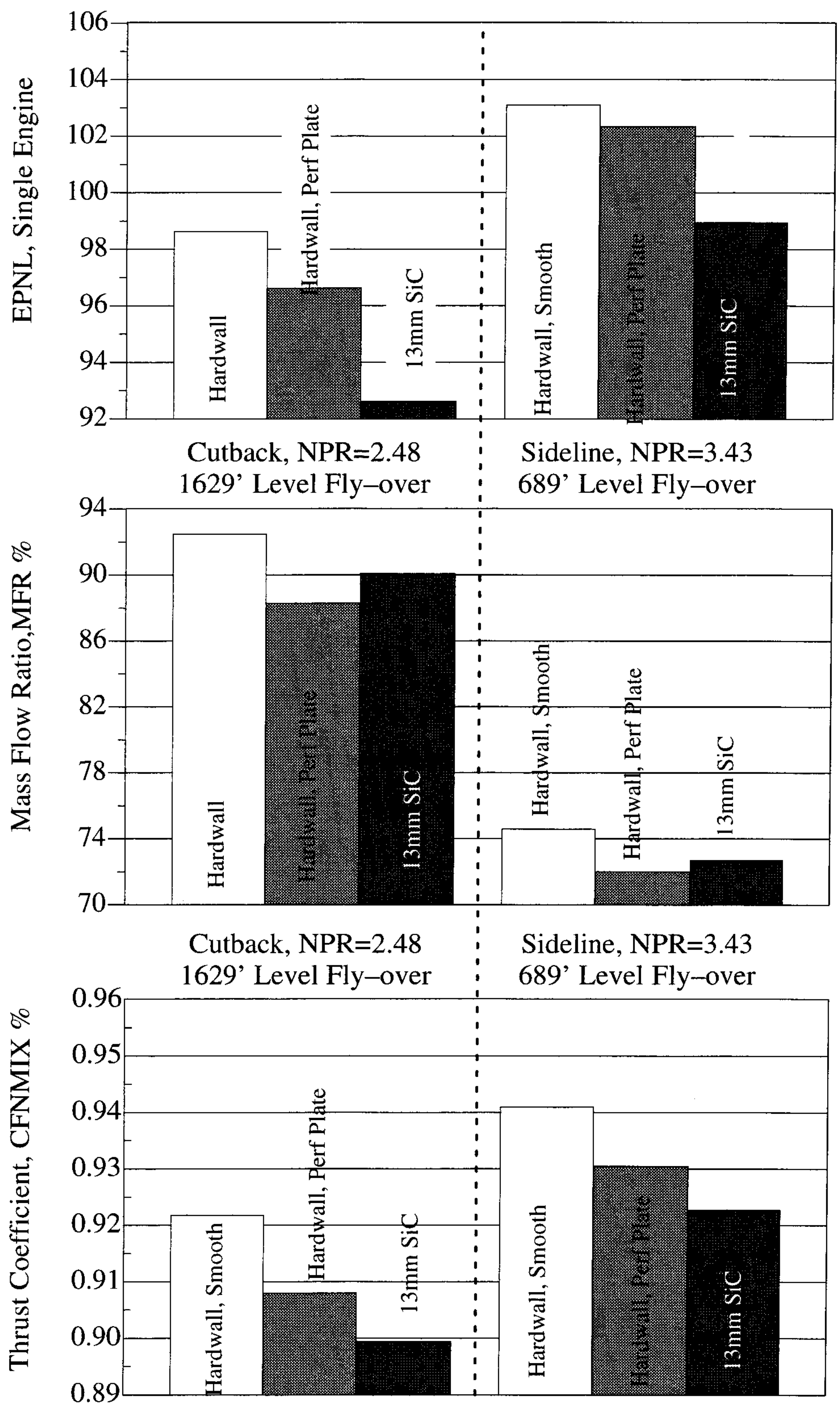


Figure 5.34, Effect of Liner on HAM Mixer 8, SAR=2.9, Mach=0.32, MAR=0.95, Short Duct, Hot Primary

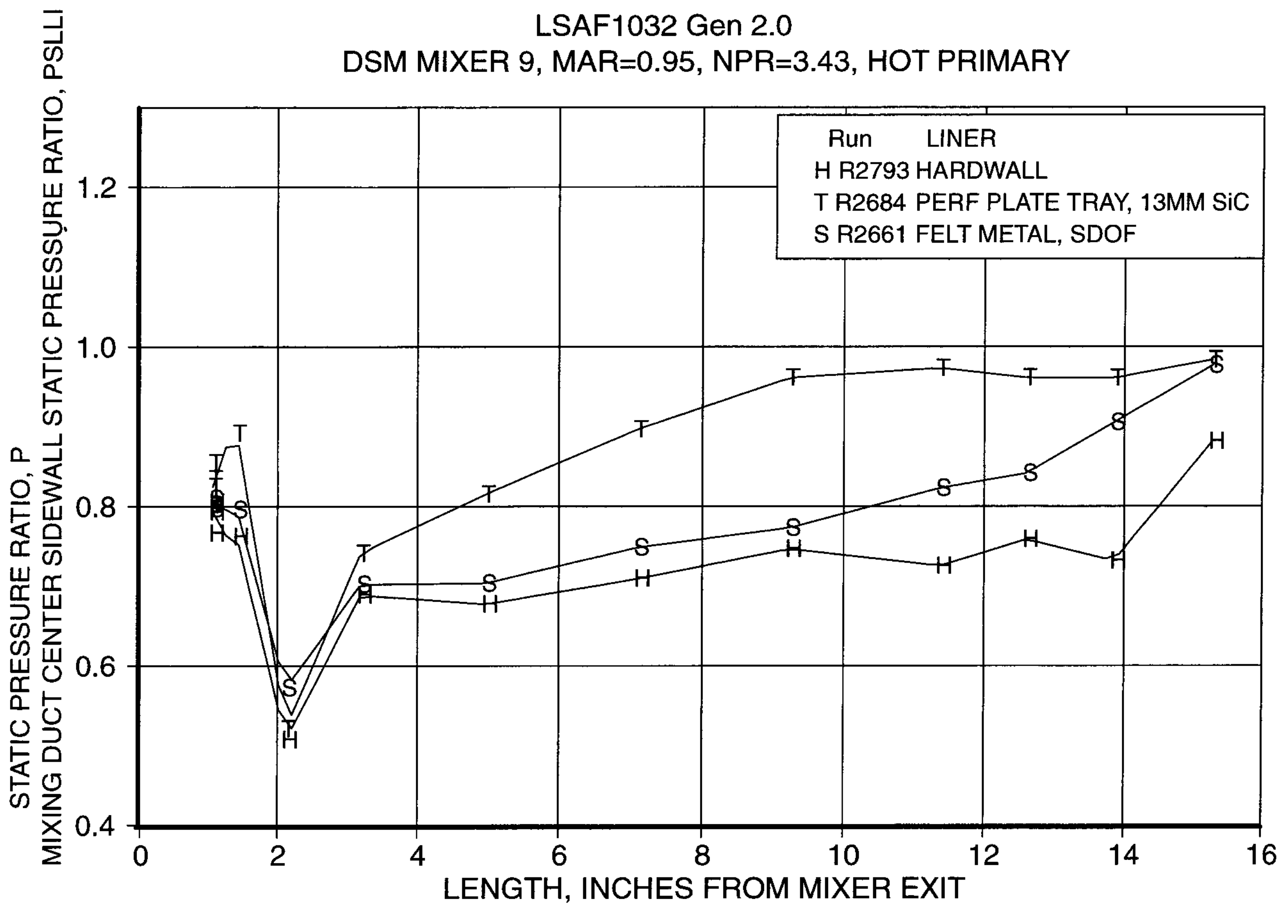


Figure 5.35, Effect of Liner on DSM Mixer 9, SAR=2.9, Mach=0.32 MAR=0.95, Hot Primary

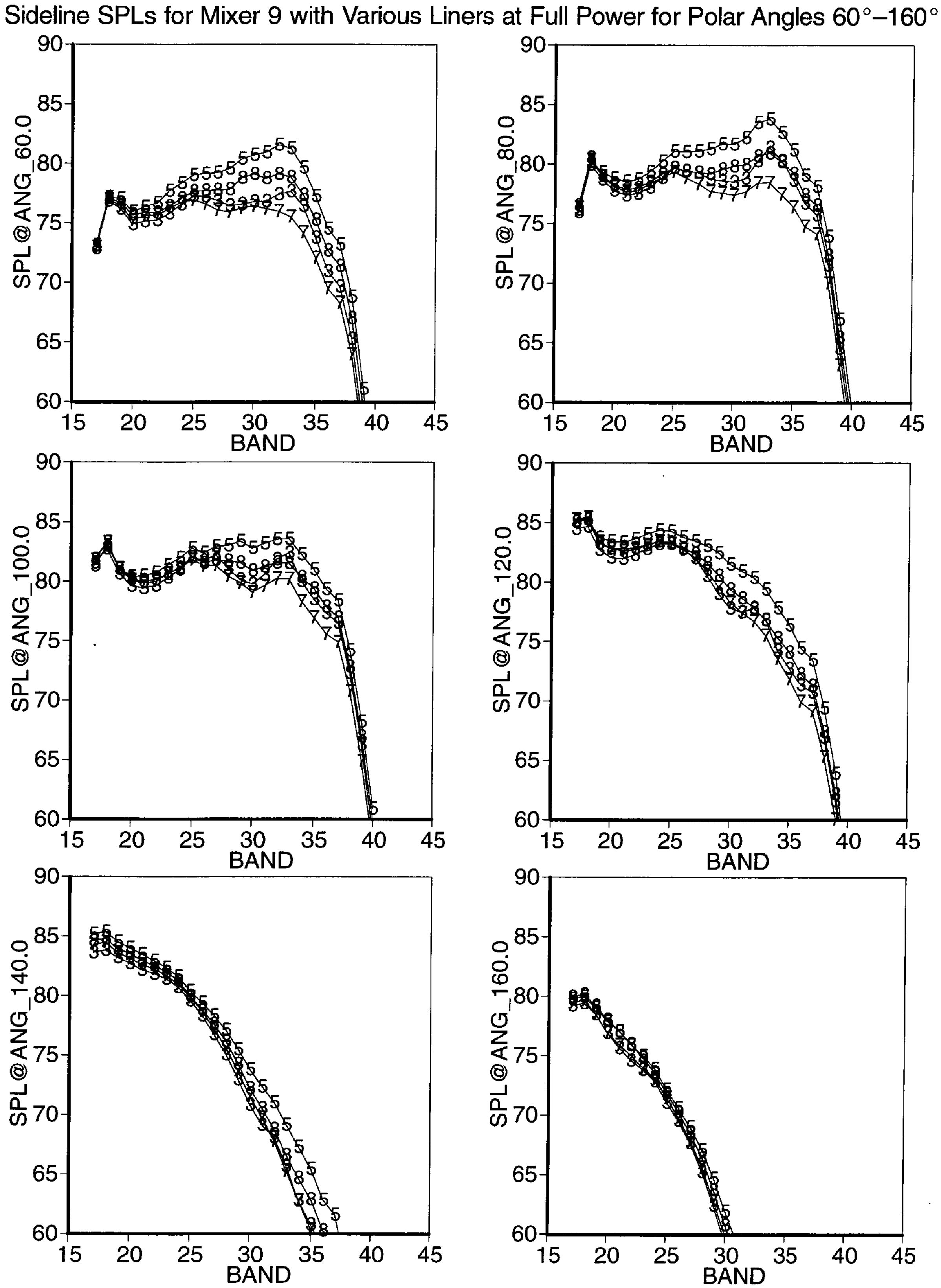


Figure 5.36, Effect of Liners on Extrapolated Spectra, DSM Model, SAR=2.9, Mach=0.24
13mm SDOF (3), Hardwall (5), 13mm SiC (7), 7mm SDOF (8)

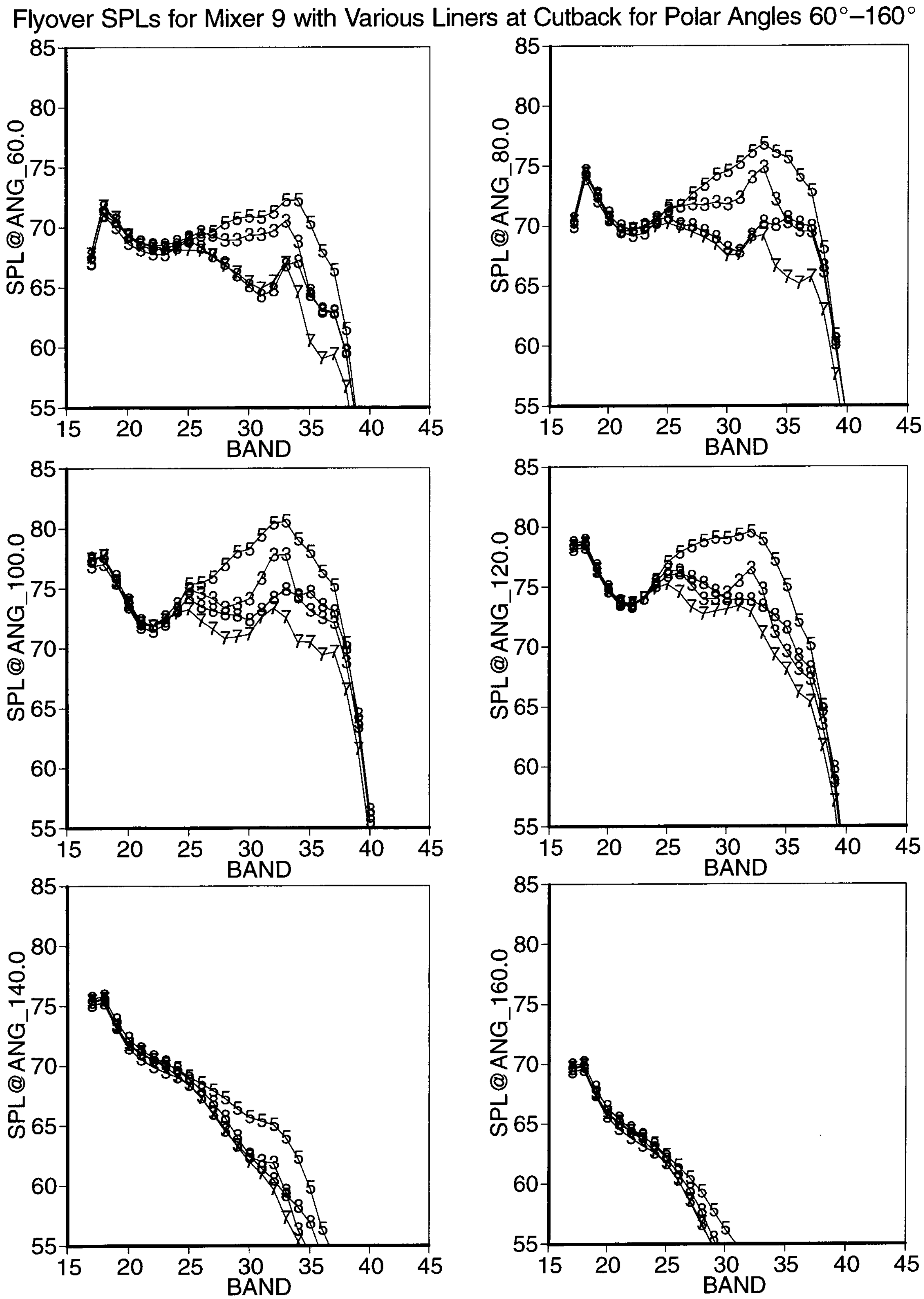


Figure 5.37, Effect of Liners on Extrapolated Spectra, DSM Model, SAR=2.9, Mach=0.24
13mm SDOF (3), Hardwall (5), 13mm SiC (7), 7mm SDOF (8)

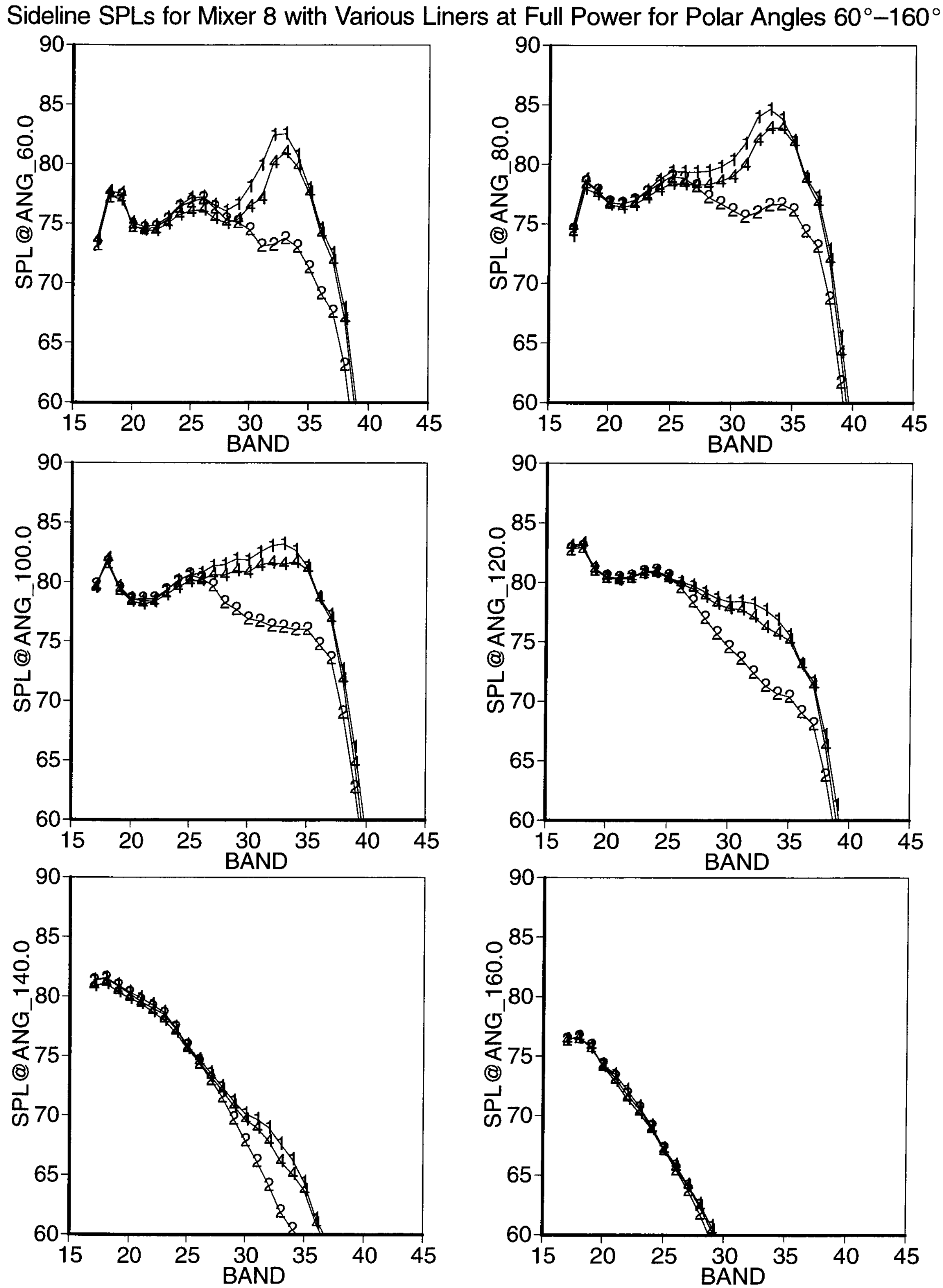


Figure 5.38, Effect of Liners on Extrapolated Spectra, HAM Model, SAR=2.9, Mach=0.32 Hardwall (1), 13mm SiC (2), Simulated Hardwall (perf sheet blocked by 2mil steel) (4).

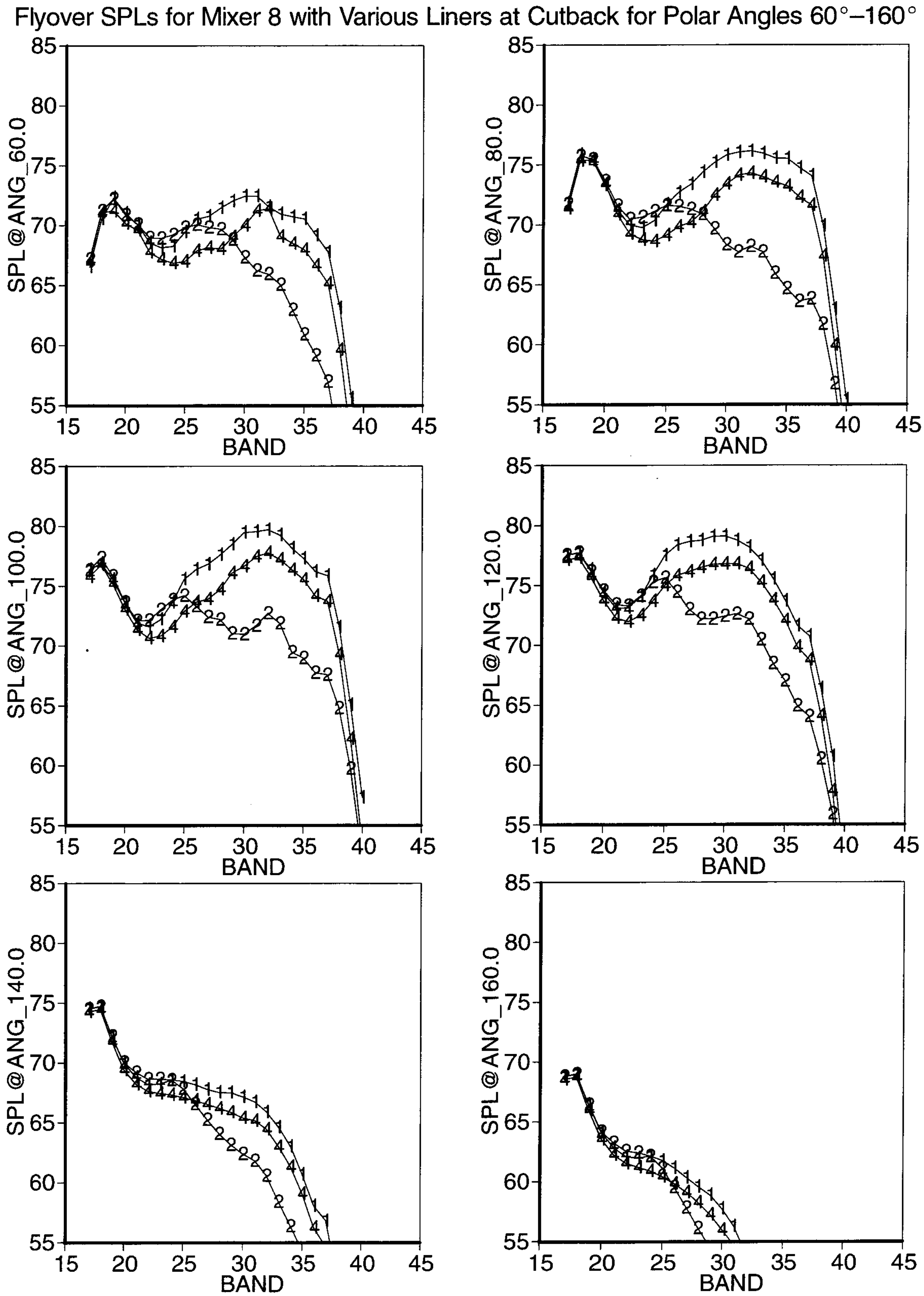


Figure 5.39, Effect of Liners on Extrapolated Spectra, HAM Model, SAR=2.9, Mach=0.32 Hardwall (1), 13mm SiC (2), Simulated Hardwall (perf sheet blocked by 2mil steel) (4).

5.8 Effect of Chute Shape

Two different chute shape concepts were tested for both the DSM and HAM mixers. Vortical mixers have straight chute walls with square corners. The sharp corners are intended to create axial vortices in the ejector to speed mixing. Best aero mixers are contoured to turn the primary and secondary streams smoothly to axial flow. Vortical mixing is minimized to reduce thrust loss. For the DSM model, vortical rotating chute and best aero style mixers were tested. The rotating chute mixer was a vortical flow mixer with straight chute walls, square lobe edges and a flapper valve at the top of each chute to set the lobe penetration. The best aero mixers were contoured axial flow mixers with lobes set at a fixed penetration. For the HAM model, NRA and best aero style chutes were tested. The NRA mixer was a vortical flow mixer with straight chute walls and square lobe edges. The NRA differed from the DSM rotating chute as it has penetration fixed at 100% and a straight section near the end of the secondary flow passage to turn the flow axially. Comparison of data between the DSM and HAM models should be made with care as the two models have many differences beyond aspect ratio. These include the axial length of the mixer chutes, the acoustic liner wetted area, and inlet lip length and contours.

Figure 5.40 shows the difference between DSM vortical and best aero chutes for thrust coefficient, aspiration, and acoustics. At sideline, the two mixer types have the same acoustic performance. The best aero mixer is about 1 EPNdB better at cutback. However, the best aero mixer has a much higher thrust coefficient (+10% at cutback and +7% at sideline). The majority of the difference in thrust performance is likely due to the flow angle difference of the primary jet. While no direct measurement was made, the estimated primary flow angle of the rotating chute was 30 to 40 degrees from the thrust axis while for the best aero it was 5 to 10 degrees. The vortical (non–axial) component of this angle is lost thrust. Another observed difference was that the rotating chute mixer (vortical) seemed to throw all the high velocity primary air to the flap walls leaving the core of the duct to be filled with secondary flow. This flow stratification can be seen to a lesser degree in the best aero mixers (Figure 5.2), but the effect was much worse for the rotating chute mixers.

Figure 5.41 shows the difference between the HAM NRA and best aero mixers for thrust, aspiration, and noise. Because the NRA mixer was at ASAR=2.86 compared to the best aero at ASAR=3.05, an adjustment was made to the best aero performance using Figure 5.10. The differences between the mixers for thrust mirrors those observed between the DSM mixers. The thrust coefficient was about 10% better at cutback and 8% better at sideline for the best aero mixer. Again, the vortical vs best aero difference is likely due to thrust loss from non–axial flow. The NRA mixer was considerably quieter at sideline than the HAM best aero mixer – by about 3.0 EPNdB. Also, a large difference in aspiration was noted between the NRA and best aero mixers. The same trend was not seen with the DSM mixers.

Figure 5.42 shows the effect of chute shape on the extrapolated noise spectra at sideline at the full power point for DSM model at SAR 2.5. High frequency mixing noise is somewhat higher with the vortical mixer and low frequency noise of the fully mixed jet is lower. At cutback power the vortical mixer has worse noise across much of the spectrum at all polar angles (Figure 5.43). Comparisons of these two types of mixers on a spectral level for a given NPR is not of great use since the thrust (and mixed jet velocities) are so much lower with the vortical mixer.

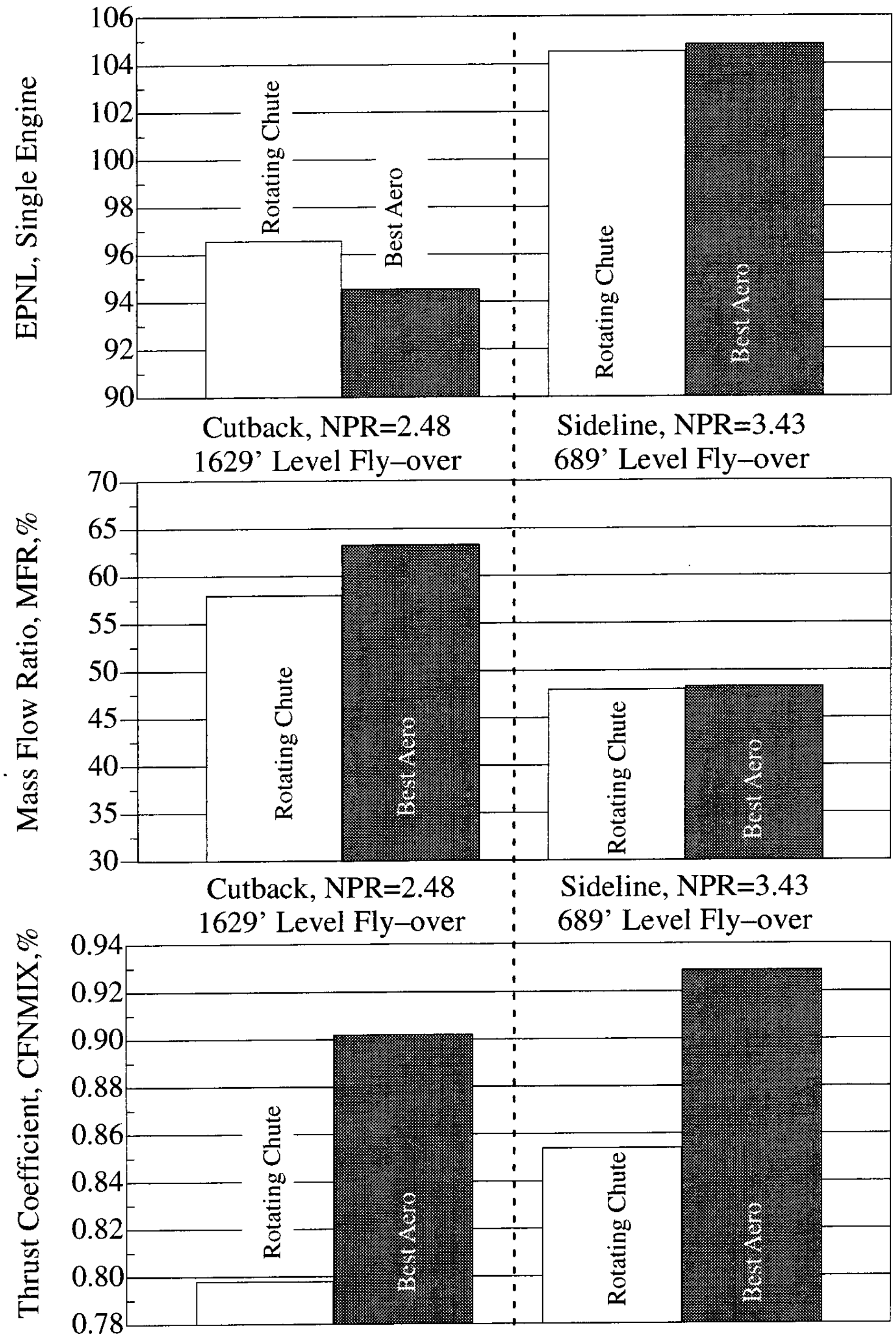


Figure 5.40, Effect of Chute Shape, DSM Rotating vs Best Aero SAR=2.5,Mach=0.245, MAR=0.95, Hot Primary

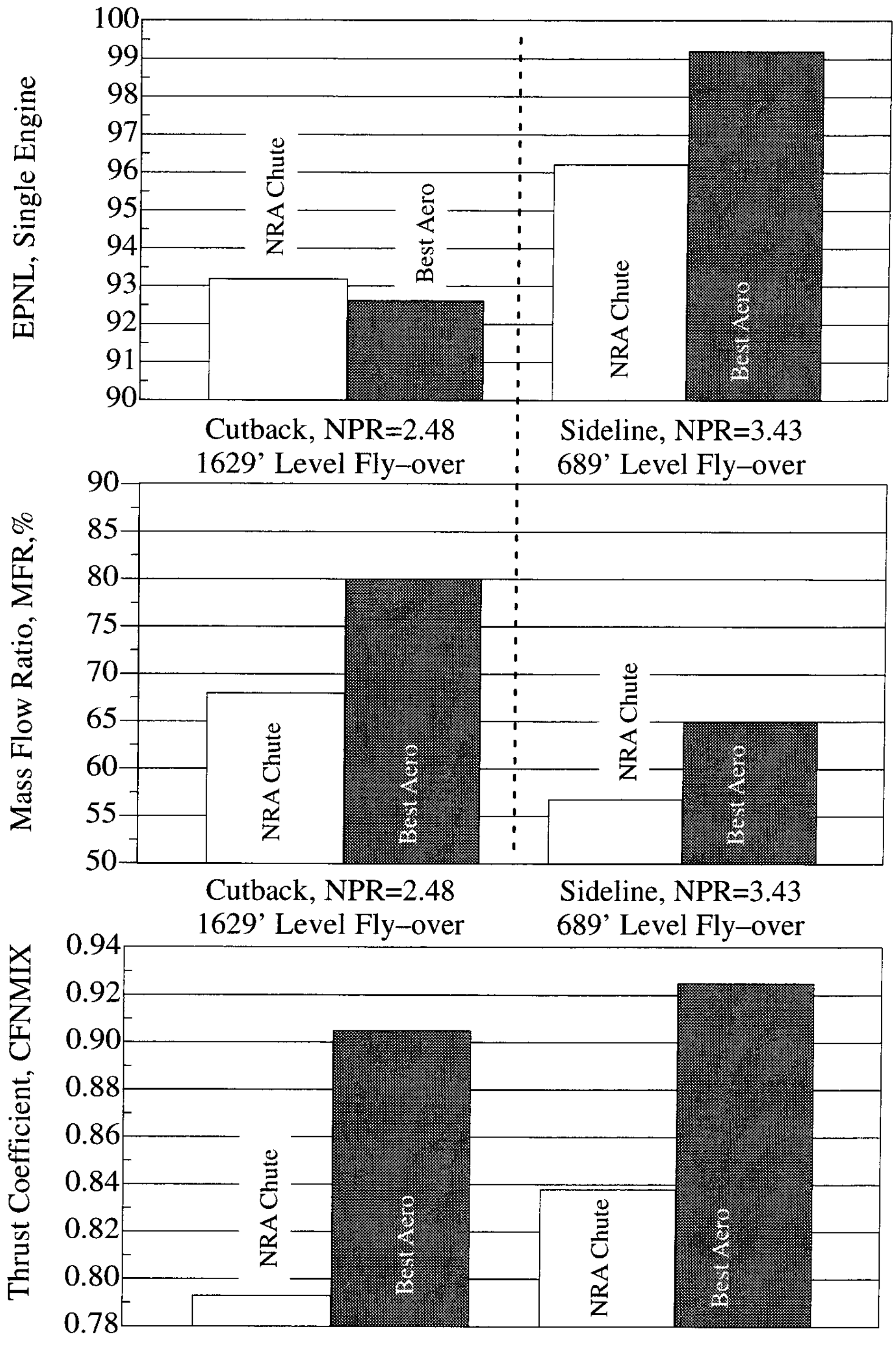


Figure 5.41, Effect of Chute Shape, HAM NRA vs Best Aero ASAR=2.86, (Mixer 8 Adjusted), Mach=0.32, MAR=0.95

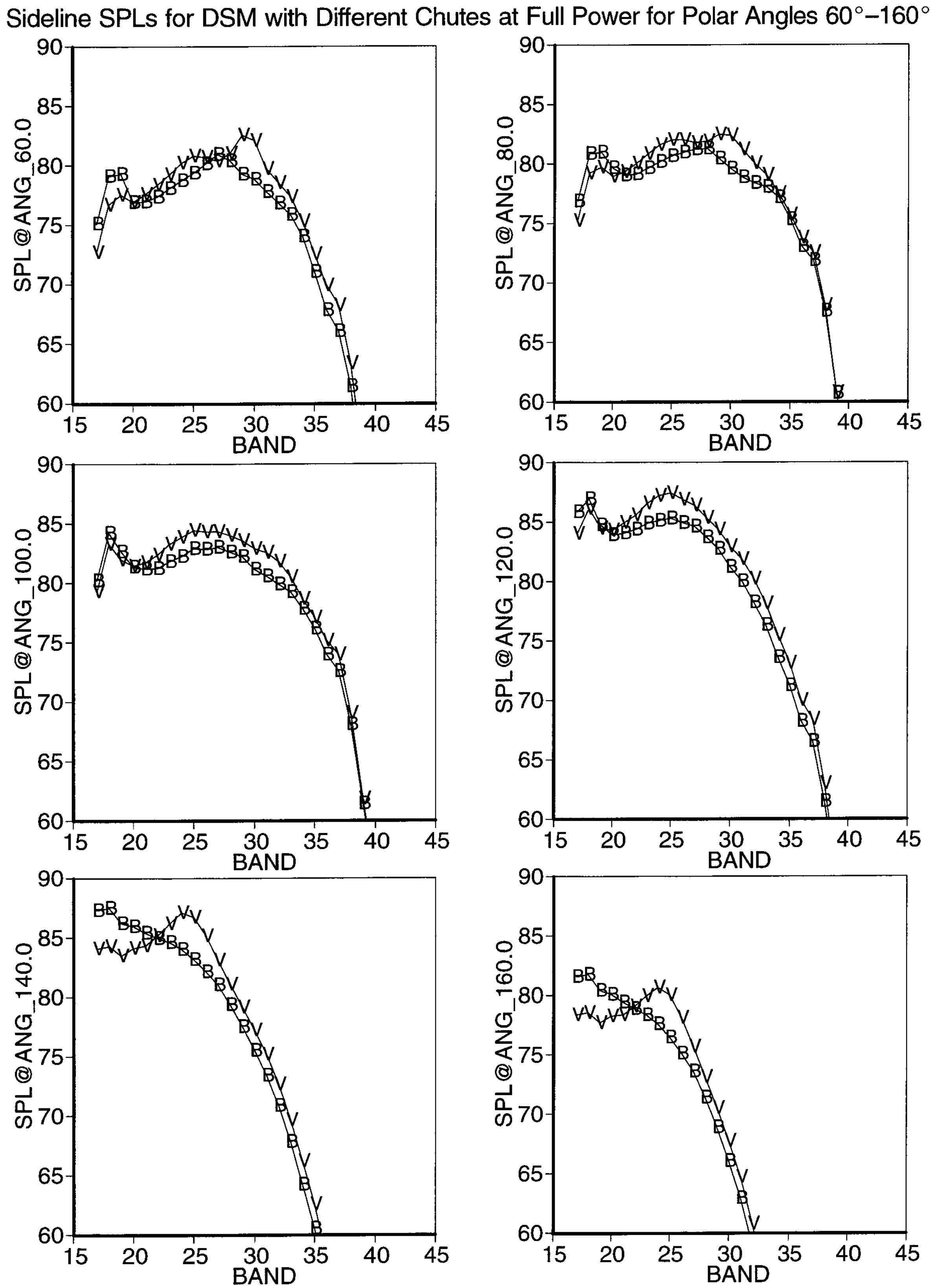


Figure 5.42, Effect of MAR on Extrapolated Spectra, DSM Model, 13mm SiC, Rotating Chute Vortical (V) and Best Aero (B) at NPR 3.43, Mach=0.32, SAR=2.5

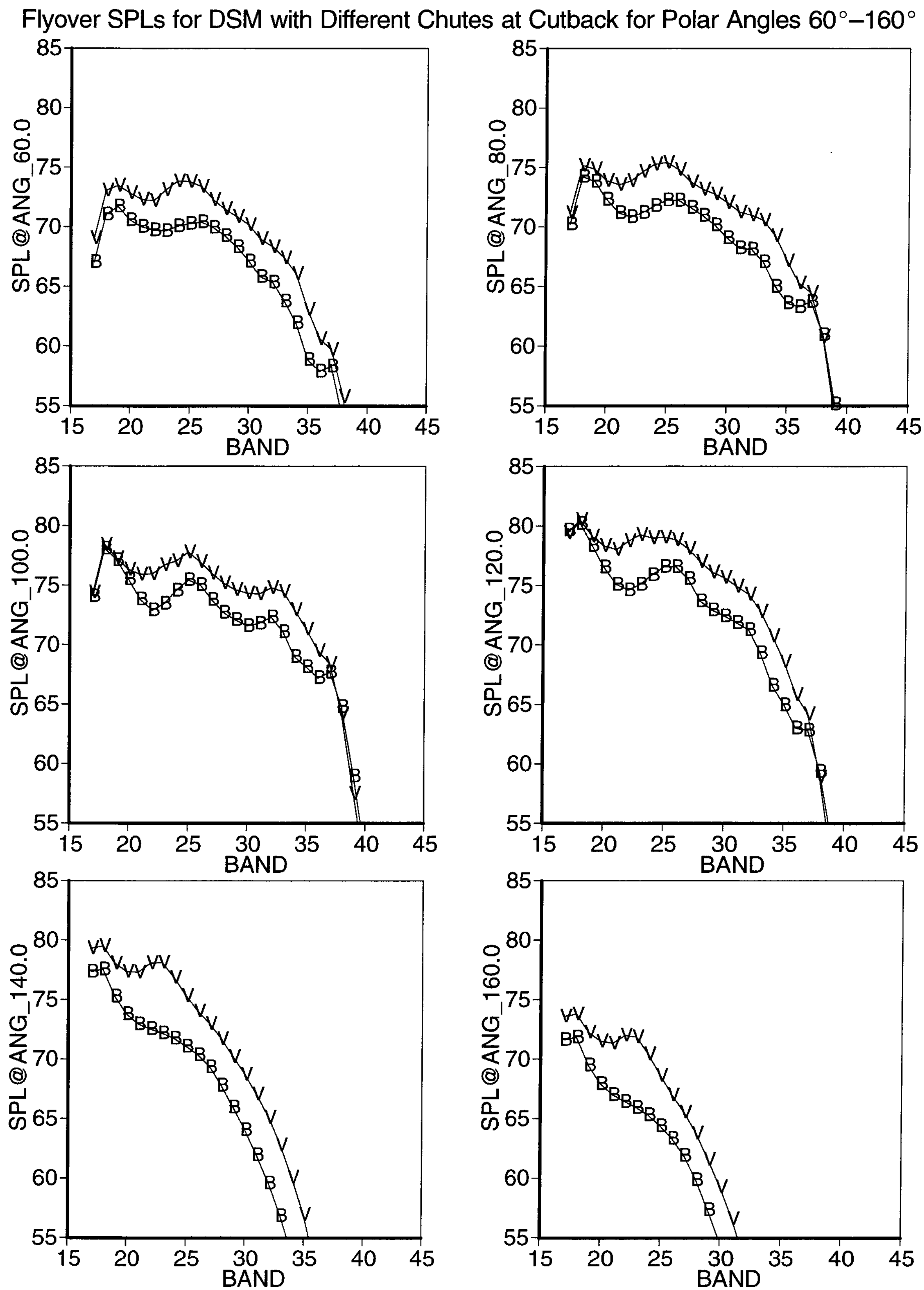


Figure 5.43, Effect of MAR on Extrapolated Spectra, DSM Model, 13mm SiC, Rotating Chute Vortical (V) and Best Aero (B) at NPR 2.48, Mach=0.32, SAR=2.5

5.9 Effect of Chevrons

The effect of the chevrons on the HAM mixers can be seen in Figure 5.44. The change in thrust coefficient is within the repeatability of the data, less than ½%. Chevrons typically reduce noise about 1 EPNdB at both cutback and sideline conditions.

Figure 5.45 shows the effect of chevrons on the extrapolated noise spectra at sideline at the full power point for HAM mixer 8. Surprisingly, a broad band noise reduction results from the addition of chevrons. One would only expect a reduction of the low frequencies with chevrons, as they should have no impact on the internal mixing. However, the chevrons' effect can be repeated and can be seen across the throttle line, including cutback power (Figure 5.46).

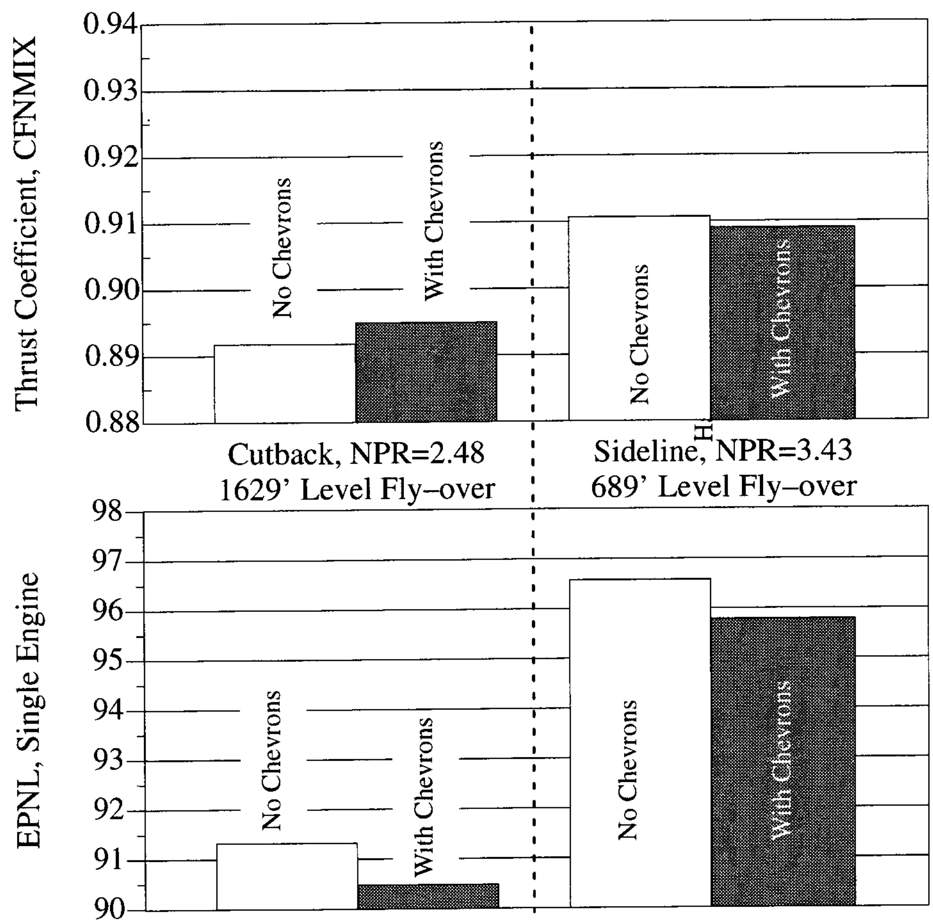


Figure 5.44, Effect of Chevrons, HAM Mixer 8, 160" Flaps, MAR=0.95, Hot Primary

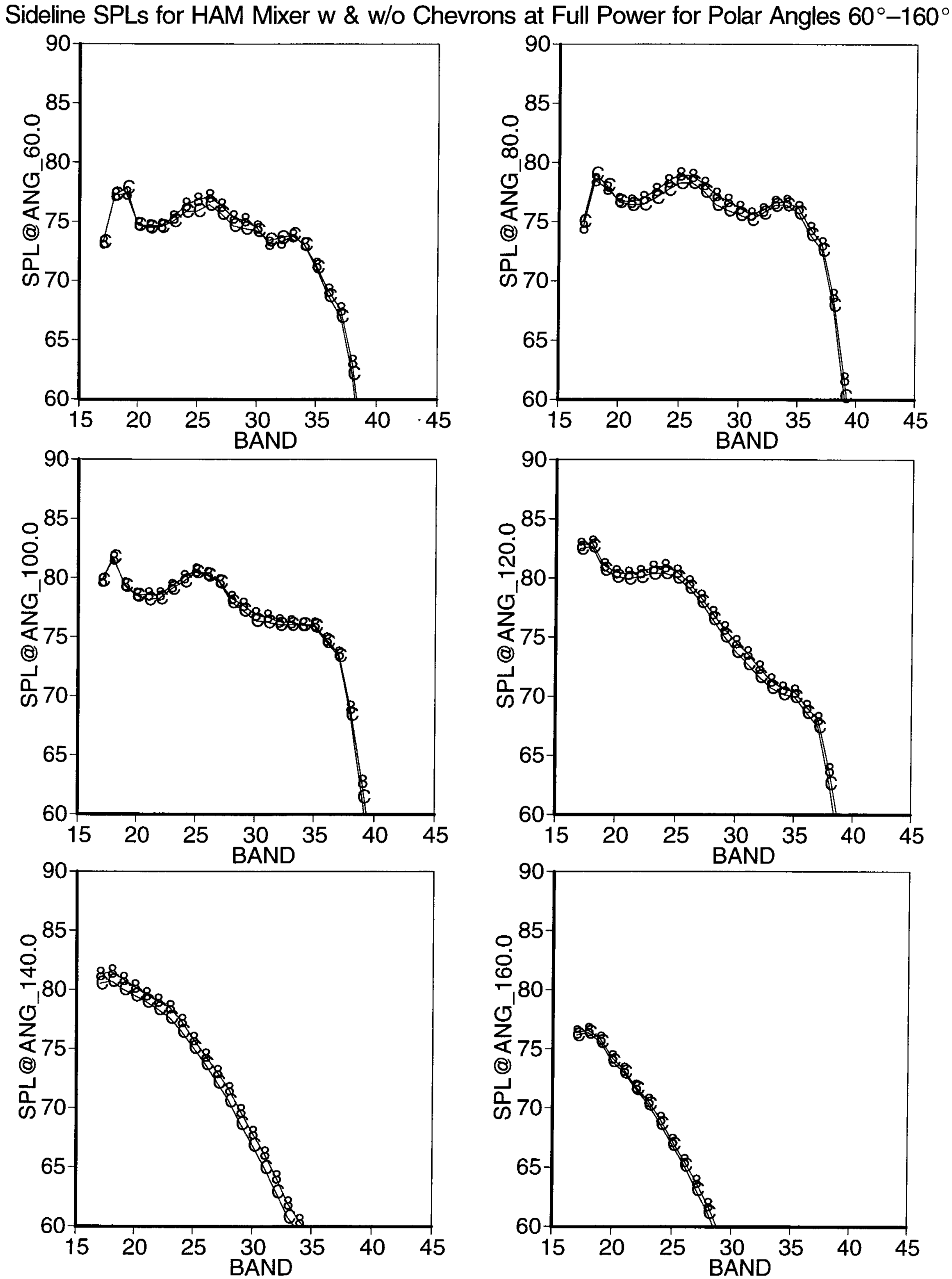


Figure 5.45, Effect of Chevrons on Extrapolated Spectra, HAM Model, SAR=2.9, 13mm SiC, Mixer 8 w/o Chevrons (8), with Chevrons (C) at NPR 3.43, MAR 0.95, Mach=0.32

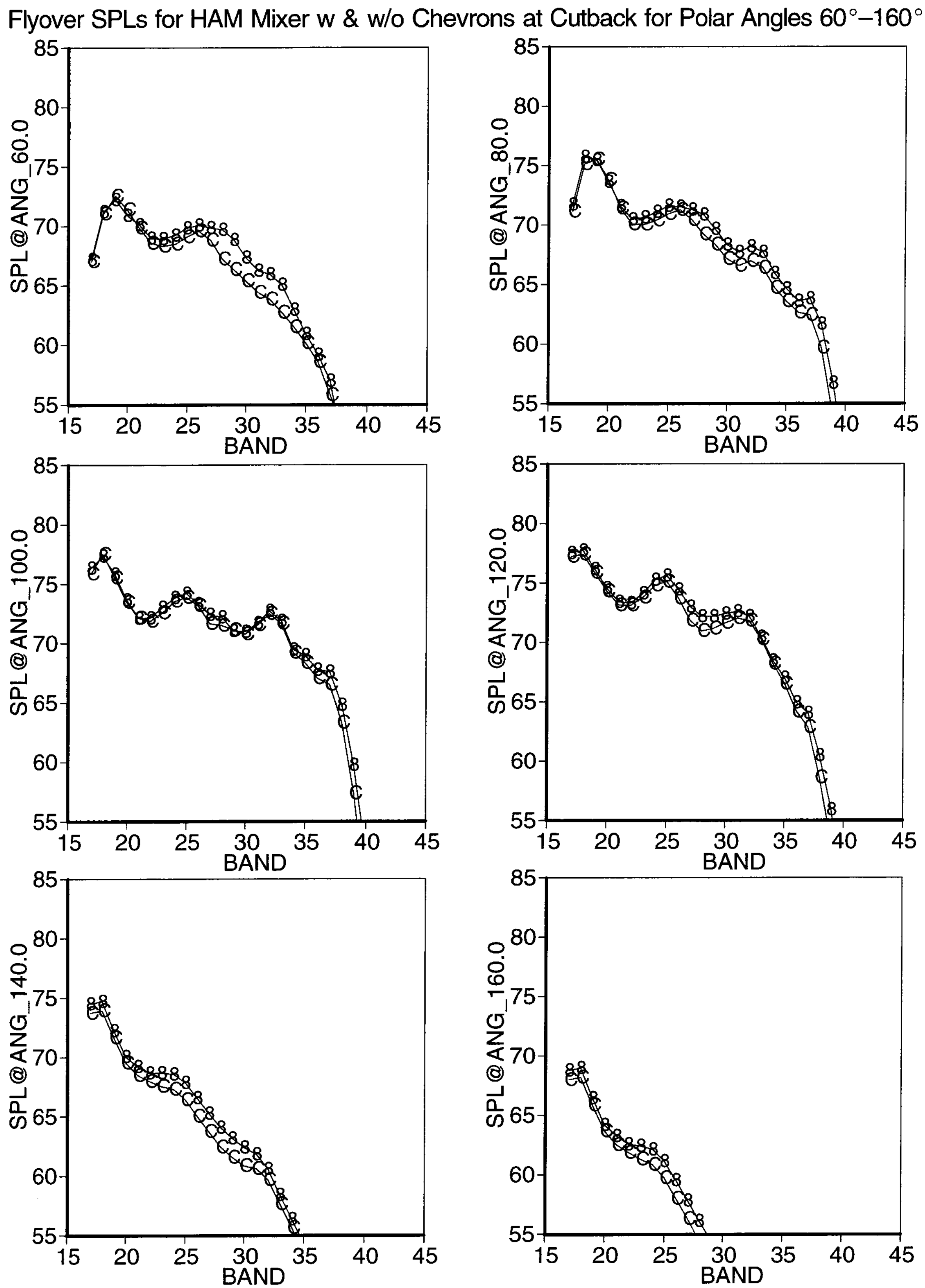


Figure 5.46, Effect of Chevrons on Extrapolated Spectra, HAM Model, SAR=2.9, 13mm SiC, Mixer 8 w/o Chevrons (8), with Chevrons (C) at NPR 2.48, MAR 0.95, Mach=0.32

6.0 Photographs

Digital photographs were acquired of the DSM and HAM models and much of the individual hardware. A few of the photographs were included in the document, but many more are available off of Compact Disks, CD. The photographs are stored on the two CD's, one for the DSM and one for the HAM models, in TIFF format that can be read into and viewed by programs available on PC, MAC, and Work Station. Only a few CD's were made, so distribution will be limited to one set per site.

7.0 Recommendations/Conclusions

The Gen 2.0 nozzle test at Boeing LSAF provided key aero/acoustic data to help support the HSCT nozzle development. A wide range in overall nozzle performance (DSM mixer 1 at cfn=0.81, sideline EPNL=101 dB to HAM mixer 8 with long flaps and chevrons at cfn=0.93, sideline EPNL=96 dB) was seen over the course of the test. Data was obtained to assess the effects on overall performance of SAR, MAR, penetration, Liner length and type, Mach number and primary temperature. The best aero, axial flow, type mixer was shown to have much better overall noise and thrust performance than the vortical flow type of mixer.

Based on the test data and airplane system studies, the best aero type of mixer is a viable concept for HSCT mixer ejector nozzles. The recommended mixer parameters from the test are – best aero, 2.9 SAR, 1.5 aspect ratio, 92.5% penetration. Chevrons are recommended if the cruise drag in the supersonic mode is minimal, and small scale mixing enhancers on the mixer lobes (small ramps, small tabs, or even small chevrons) should be considered if they can be added with minimal thrust loss. Since the acoustic treatment is more effective when rapid mixing occurs, successful mixing enhancement could allow shortening of the ejector. When testing scale models, such as the Gen 2.0, it is recommended that the liner face sheet be felt metal rather than the porous trays. The felt metal more closely represented the full scale liner losses eliminating some of the scaling issues.

Additional nozzle testing where acoustic and thrust data are measured concurrently needs to be done to continue the progress made toward a viable nozzle system for the HSCT airplane. Great strides were made during the GEN2 nozzle test toward this end, but additional work is needed. Gaining understanding of the mixing process is of particular importance. And further study of the effect of lining, on flow as well as noise, needs to be continued. Finally, we must learn how the chevrons were able to reduce broadband noise with no apparent thrust loss. This work is currently planned in the GEN 2.5 and 3.0 test series scheduled to occur during 1997 and 1998.

References

1) CM BO96–054–N, "Boeing FSC Pratt 5 Hole Probe Calibration", L.D. Arney, 17, Sept 1996.

2) CM BN–095–032–N, "Gen 2.0 Aero/Acoustic Performance Nozzle Model Test Plan for LSAF", D.L. Sandquist, 21 June 1995.

3) CM BN–096–009–N, "HAM Aero/Acoustic Performance Nozzle Model Test Plan for LSAF", L.D. Arney/D.L. Sandquist, 28 May, 1996.

4) CM GE94–085–N, "Model Design Information to ensure consistent effort between GE and P&W", Bob Ellerhorst, 12 August 1994.

5) CM B096–034–N, "DSM Mixer #4 Exit Rake Contour Plots", D. Sandquist, 9 August, 1996.

6) CM B096–035–N, "DSM Mixer #5 Exit Rake Contour Plots", D. Sandquist, 9 August, 1996.

7) CM B096–036–N, "DSM Mixer #6 Exit Rake Contour Plots", D. Sandquist, 9 August, 1996.

8) CM B096–037–N, "DSM Mixer #9 (952.576) Exit Rake Contour Plots", D. Sandquist, 9 August, 1996.

9) CM B096–038–N, "DSM Mixer #9 (953.576) Exit Rake Contour Plots", D. Sandquist, 9 August, 1996.

10) CM B096–039–N, "DSM Mixer #9 (972.576) Exit Rake Contour Plots", D. Sandquist, 9 August, 1996.

11) CM B096–040–N, "DSM Mixer #9 (973.576) Exit Rake Contour Plots", D. Sandquist, 9 August, 1996.

12) CM B096–031–N, "HAM Mixer #8 Exit Rake Contour Plots", D. Sandquist, 24 July, 1996.

13) CM BO96–026–N, "HAM Mixer #4 Exit Rake Contour Plots", D. Sandquist.

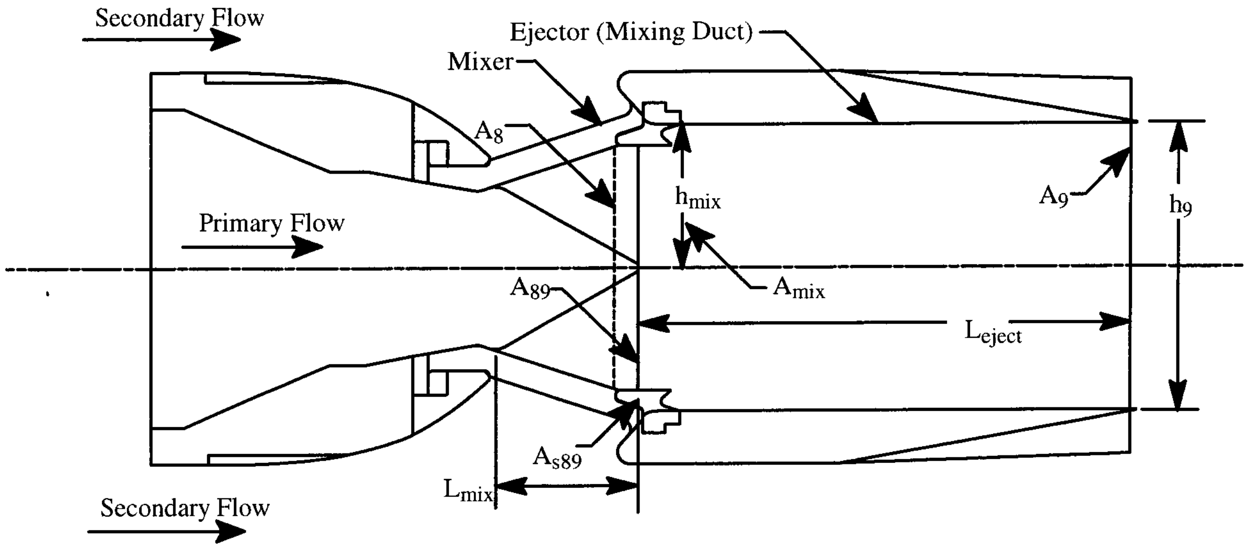
14) CM BO96–059–N, "LSAF 1039, HAM Gen 2.0 Mixing Duct Static Pressure Profiles.", D.L. Sandquist, 24, September, 1996

15) CM B096–067–N, "LSAF 1032, DSM Gen 2.0 Mixing Duct Static Pressure Profiles", L.D. Arney, 22, November, 1996.

Nomenclature

ASAR	Aerodynamic Suppressor Area Ratio, (Amix/Achk)
Achk	Primary Nozzle choked Flow Area
Aexit	Nozzle Exit Area
Amix	Mixing Duct Reference Area
cfn	primary nozzle net thrust coefficient, (Fmeas/Fip)
DSM	Down Stream Mixer
EPNL	Effective Perceived Noise Level
Fip	Ideal Primary Thrust, (Wpri/Vip)
Fmeas	Measured Thrust
ft/s	Feet per Second
Gen 2.0	Generation 2.0
HAM	Hot Acoustic Mixer
LSAF	Low Speed Aeroacoustic Facility
MAR	Mixer Area Ratio, (Amix/Aexit)
mfr	mass flow ratio, aspiration, (Wsec/Wpri)
NPR	Primary Nozzle Pressure Ratio, (Ptp/Pa)
NRA	National Research Announcement
PEN	Penetration
Pa	Ambient Pressure, Psi
Psi	Pounds per Square Inch
Ptp	Primary Nozzle Pressure, Psi
SAR	Suppressor Area Ratio, (Amix/Apri)
SDOF	Single Degree of Freedom
SiC	Silicon Carbide
Vip	Primary Nozzle Ideally Expanded Velocity, ft/s
Wsec	Secondary Mass Flow lbm/s
Wpri	Primary Mass Flow lbm/s

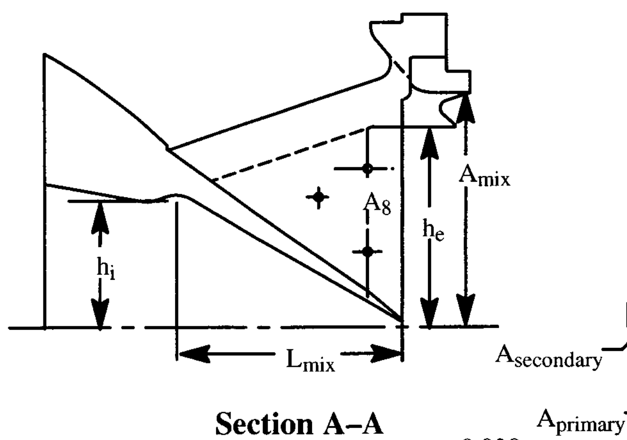
Appendix A

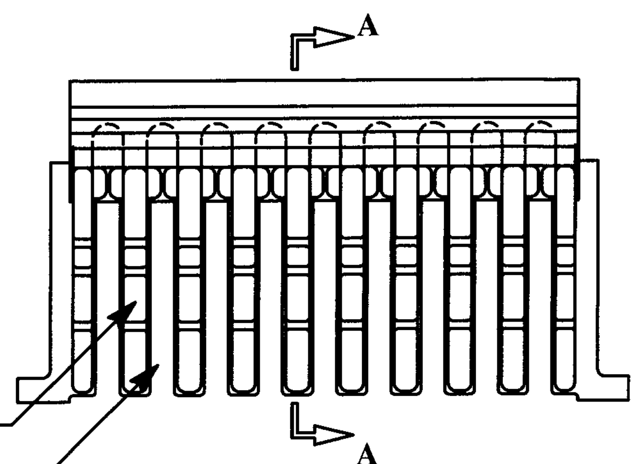


Primary flow mixer throat area $= A_8$
Primary flow mixer exit area $= A_{89}$
Mixer length $= L_{mix}$
Mixing plane area $= (A_{mix}) = 2 \times W_T \times h_{mix}$
Ejector L/D $= L_{eject}((\pi)/(4A_8))^{1/2}$
Suppressor Area Ratio (SAR) $= A_{mix}/A_8$
Mixing Duct Area Ratio (MAR) $= A_9/A_{mix}$
Area Chute Expansion Ratio (CER)$= A_{89}/A_8$

h_{mix} = Height from center line of flow path at the entrance of the mixing duct
W_T = Overall mixing duct width
A_{Base} = Mixer chute base area
h_9 = Overall mixing duct exit height
A_9 = $W_T \times h_9$

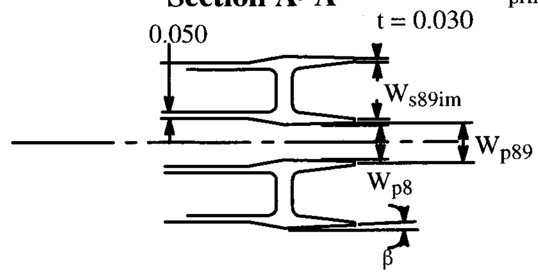
Upper Half Shown





Mixing Plane

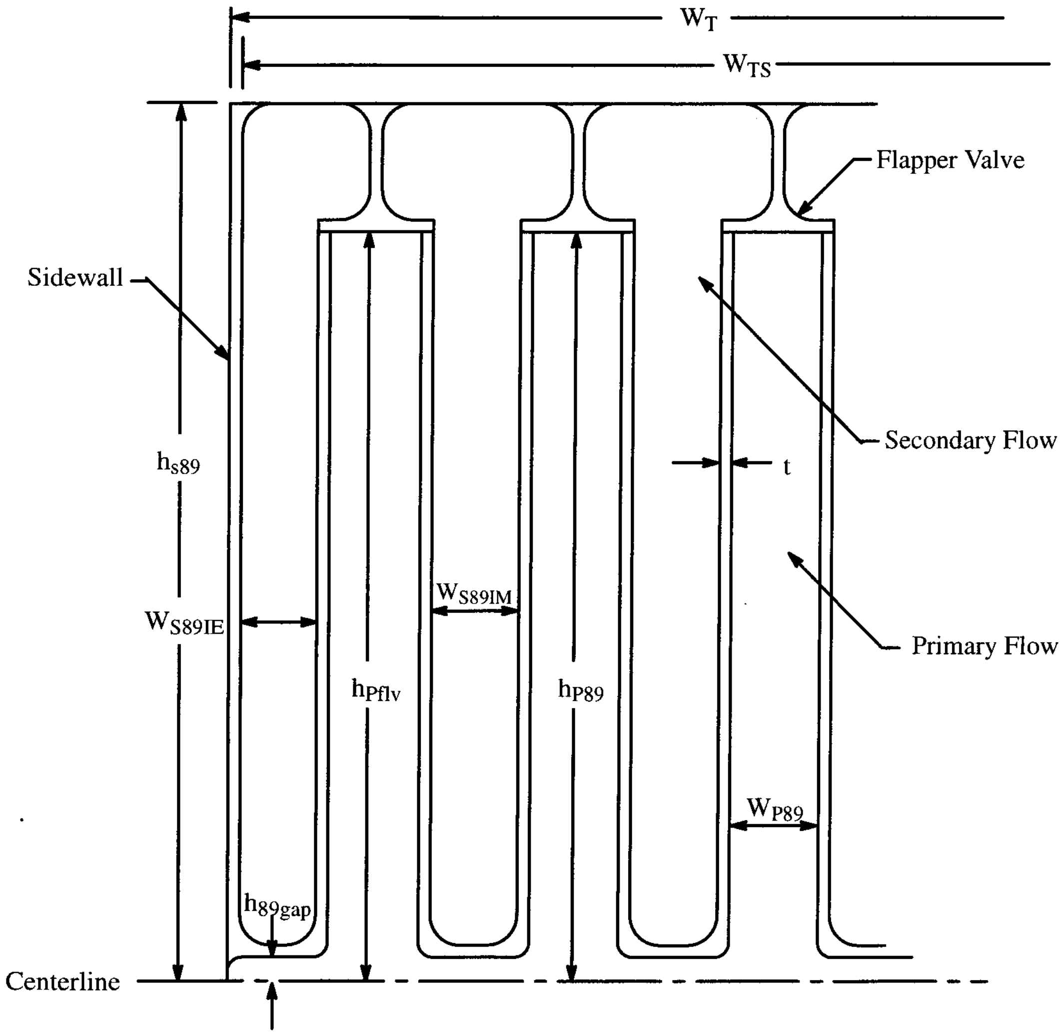
Section A–A



Mixer Throat Area $=A_8$
Mixer Exit Area $= A_{89}$
Mixer Divergence Angle $= \beta$
Mixer L/D $= L_{mix}/(4(Aj/\pi))^{1/2}$
Local Chute Expansion Ratio (CER) $= A_p/A_j$

Gen 2.0 Mixer Ejector Aero Parameter Key

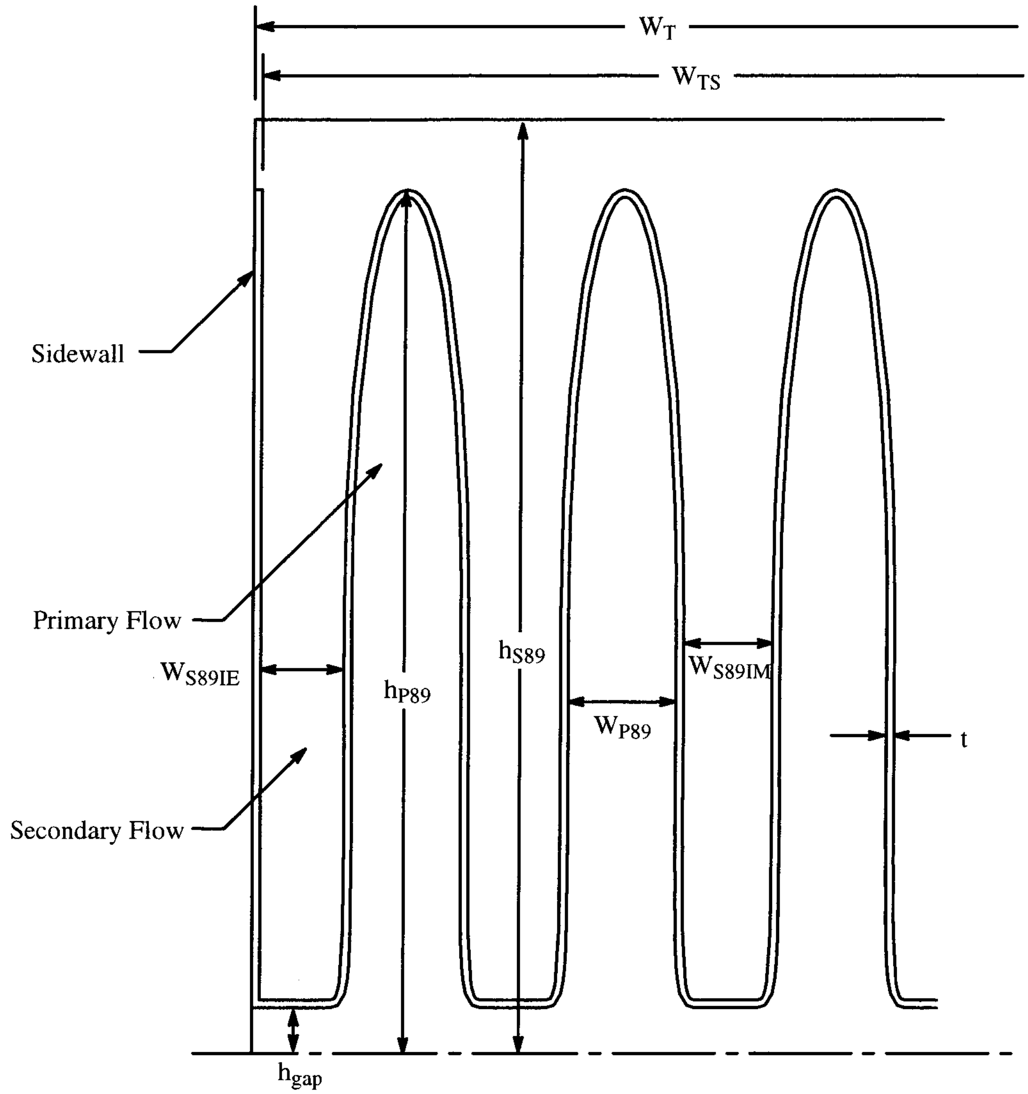
Appendix A



h_{S89} = height from centerline of secondary flow path at chute exit plane
h_{89gap} = height from centerline of primary flow path to bottom of chute at the exit plane
h_{mix} = height from centerline of primary flow path at entrance of the mixing duct (not shown)
h_{pflv} = height from centerline of primary flow path at chute exit plane to primary flow side of flapper valve
h_{P89} = height from centerline of primary flow path at chute exit plane
W_{S89IM} = middle chute width at chute exit plane, (excludes metal thickness)
W_{S89IE} = edge (sidewall) chute width at chute exit plane, (excludes metal thickness)
W_{p89} = primary flow width between chutes at chute exit plane
W_T = total nozzle width
W_{TS} = total secondary nozzle width = $\{2W_{S89IE} + [(N_s/2)-2]W_{S89IM} + (N_p/2)W_{p89} + [(N_p + N_s)/2 - 1]t\}$
t = chute wall trailing edge thickness
N_s = number of secondary chutes
N_p = number of primary flows
A_{89} = primary flow area at chute exit plane = 2{(Wt x h89gap) + [(Np/2) x (ha89–h89gap) x Wp89]}
A_{S89} = secondary flow area at chute exit plane = $2\{h_{s89} \times W_{TS} - A_{89} + h_{89gap} \times W_{TS}\}$
P_{P89} = primary flow shear length (100% penetration) = $4 \times h_{89gap} + N_p \times W_{p89}$
(less than 100% penetration) = $4 \times h_{89gap}$
P_{mix89} = mixing layer shear length (100% penetration) = $2\{N_p \times (h_{pflv} - h_{89gap})\}$
(less than 100% penetration) = $2\{N_p \times (h_{pflv} - h_{89gap}) + W_T\}$
P_{S89} = secondary flow shear length (100% penetration) = $2\{W_T + 2(h_{mix} - h_{89gap})\}$
(less than 100% penetration) = $2\{W_T - (N_p/2)W_{p89} + 2(h_{mix} - h_{89gap})\}$

Geometric Definition of Exit Plane – DSM Mixer

Appendix A



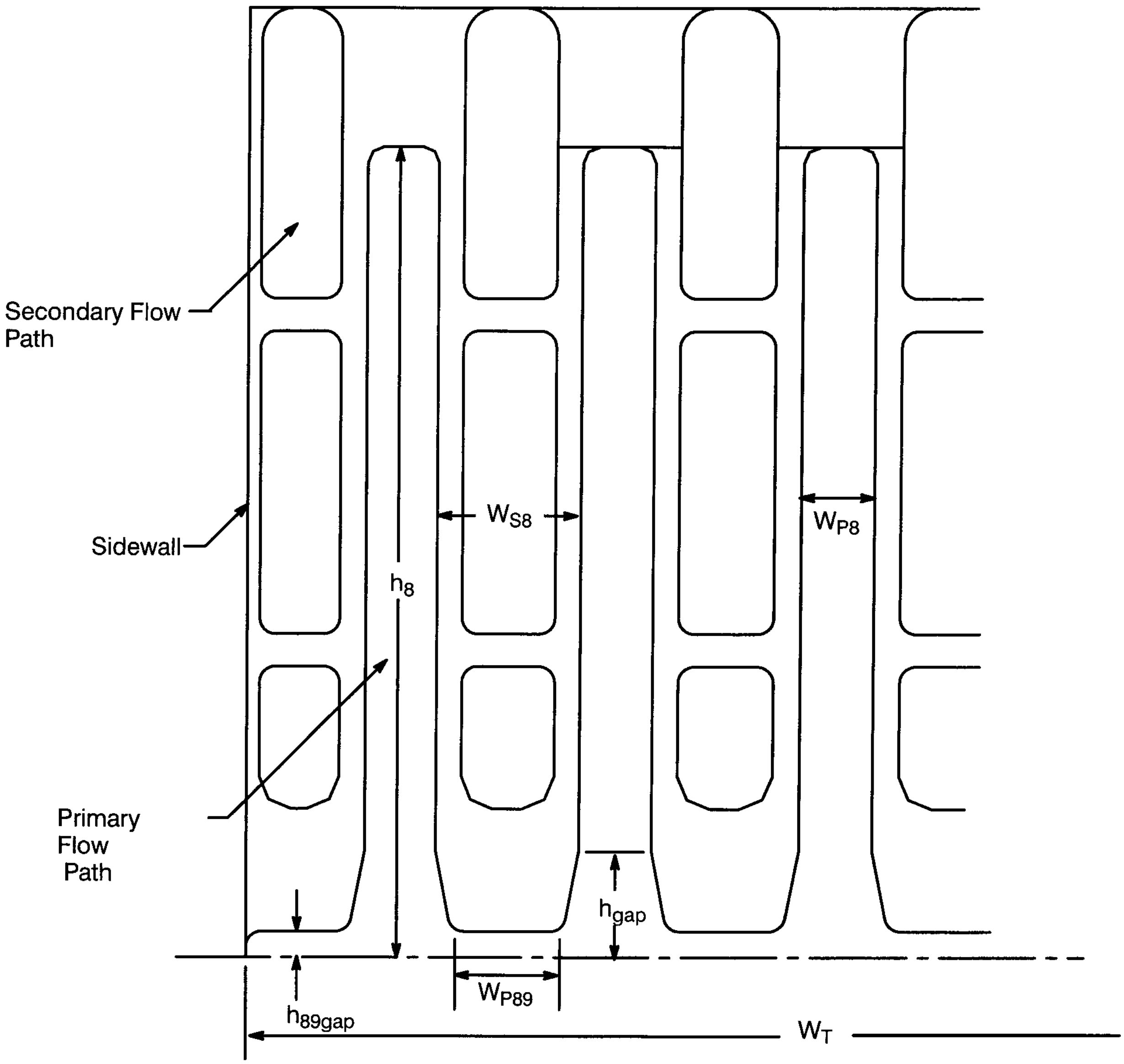
$h89_{gap}$ = gap between bottom of chutes and nozzle centerline
h_{P89} = height from centerline of primary flow path at chute exit plane (includes metal thickness)
h_{S89} = height from centerline of secondary flow path at chute exit plane
h_{mix} = height from centerline of primary flow path at entrance of mixing duct (not shown)
t = chute wall trailing edge thickness
W_T = total nozzle width
W_{TS} = total secondary nozzle width = $\{2W_{S89IE} + [(N_s/2)–2]W_{S89IM} + (N_p/2)W_{p89} + [(N_p + N_s)/2 – 1]t\}$
W_{S89IE} = end (sidewall) chute width at chute exit plane, (excludes metal thickness)
W_{S89IM} = middle chute width at chute exit plane, (excludes metal thickness)
W_{P89} = primary flow width between chutes at chute exit plane
A_{89} = primary flow area at chute exit plane (area calculated from CAD definition)
A_{S89} = secondary flow area at chute exit plane (area calculated from CAD definition
P_{P89} = primary flow shear length (100% penetration, calculatied from CAD definition)
(less than 100% penetration) = $4h_{gap}$
P_{mix89} = mixing layer shear length, (area calculated from CAD definition)
P_{S89} = secondary layer shear length (less than 100% penetration) = $2\{W_T + 2(h_{mix} – h_{gap})\}$
(100% penetration, calculated from CAD definition)

Geometric Definition of Exit Plane – Best Aero Shape

Mixer 2, 7mm SiC / 13mm SiC Forward Hardwall						
	Conf 262.200, MAR=0.95, Pen=92.5%				Conf 292.200, MAR=0.95, Pen=92.5%	
	Cold Primary		Hot Primary		Hot Primary	
NPR	M=0.0	0245	0.0	0.245	0.0	0.245
1.51			842	850	796	790
1.99	838	864	843	851	797	791
2.48	839	865	844,845	852,853	798	792
2.96	840	866	846	854,858		793
3.20				859		
3.43	841	867	847,848	855,856,860	799	794
3.60				861		
3.80				862		
4.00	837	863	849	857		795

Conf 262.202, Mixer 2, 7mm SiC, Mixer Exit Rakes				
	Cold Primary		Hot Primary	
NPR	M=0.0	0245	0.0	0.245
1.99	824	833		
2.48	825	834	828	830
2.96	826	835		
3.43	827	836	829	831
4.00	823	832		

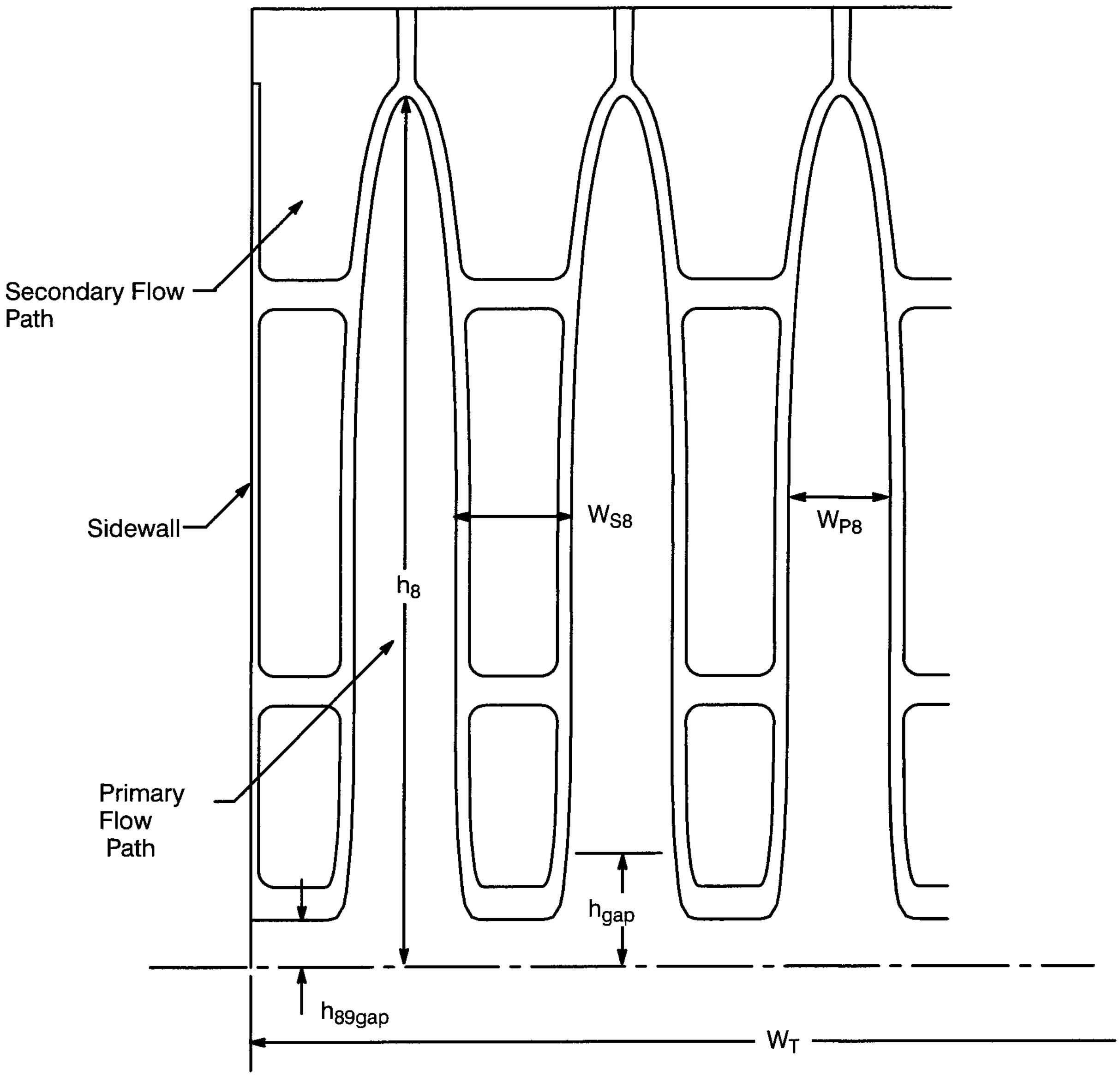
Appendix A



h_{gap}	= gap between bottom of chutes and centerline of primary flow path at nozzle throat
h_{89gap}	= gap between bottom of chutes and centerline of primary flow path at chute exit plane
h_8	= height from centerline of primary flow path at nozzle throat
W_{P8}	= width of primary flow path lobe at nozzle throat
W_{S8}	= width of secondary chute (including metal thickness) at nozzle throat
W_{P89}	= width of primary flow path lobe at mixer exit
W_T	= total nozzle width
N_P	= number of primary chutes
A_8	= primary flow area at nozzle throat

$$= 2\{[(h_8 - h_{gap}) \times W_{P8} \times (N_P/2)] + (h_{89gap} \times W_T) + [((W_{P89}+W_{P8})/2) \times (N_P/2) \times (h_{gap} - h_{89gap})]\}$$

Geometric Defintion of Throat – DSM Mixer



h_{gap} = gap between bottom of chutes and centerline of primary flow path at nozzle throat
h_{89gap} = gap between bottom of chutes and centerline of primary flow path at chute exit plane
h_8 = height from centerline of primary flow path at nozzle throat
W_{P8} = width of primary flow path lobe at nozzle throat
W_{S8} = width of secondary chute (including metal thickness) at nozzle throat
W_T = total nozzle width
N_P = number of primary chutes
A_8 = primary flow area at nozzle throat (calculated from CAD system)

Geometric Definition of Throat – Best Aero Shape

Appendix A

DSM Mixer Dimensions

	Type	SAR	Pen (%)	N_s	N_p	A_{mix} (in^2)	A_8 (in^2)	A_{89} (in^2)	A_{S89} (in^2)	W_{p8} (in)	W_{s8} (in)	W_{p89} (in)	W_{s89ie} (in)	W_{s89im} (in)	W_{sie} (in)	W_{sim} (in)	W_T (in)	W_{TS} (in)
1	DSM	3.51	85.0, 100.0	20	18	58.00	16.509	18.065 18.993	45.173 44.245	.275	.475	.303	.390	.477	.341	.363	7.90	7.86
2	DSM	2.493	85.0, 92.5, 100.0	20	18	58.00	23.269	25.233 26.677 26.667	38.590 37.156 37.156	.396	.536	.436	.327	.340	.280	.307	7.90	7.84
4	Best Aero	2.5	100.0	20	18	58.00	23.693	24.525	33.167	.361	.474	.388	.355	.387	.323	.324	7.90	7.84
5	Best Aero	2.5	92.5	20	18	58.00	23.771	24.659	36.985	.391	.449	.424	.354	.415	.320	.347	7.90	7.84
6	Best Aero	2.5	85.0	20	18	58.00	23.194	24.755	36.889	.432	.411	.467	.287	.315	.288	.318	7.90	7.84
8	Best Aero	2.2	92.5	20	18	58.00	27.292	28.192	33.514	.452	.383	.492	.262	.288	.261	.286	7.90	7.84
9	Best Aero	2.9	92.5	20	18	58.00	19.984	21.181	40.463	.330	.506	.354	.384	.417	.354	.358	7.90	7.84

	h_{gap} (in)	h_8 (in)	h_{s89} (in)	h_{p89} (in)	h_{pflv} (in)	h_{89gap} (in)	h_{mix} (in)	CER local	CER area	L_{CER} (in)	β (deg.)	L_{mix} (in)	L_{89mix} (in)	t (in)	P_{p8} (in)	P_{p89} (in)	P_{mix89} (in)	P_{S89} (in)	A_{Base} (in^2)
1	.412	3.113	4.021	3.134 3.304	3.134 3.671	.094	3.671	1.102	1.094 1.272	.550	1.46	3.71	1.053	.030	114.684	0.376 5.830	125.24 128.77	30.108 24.654	4.599 4.679
2	.412	3.134	4.071	3.120 3.304 3.304	3.120 3.395 3.671	.094	3.671	1.229	1.084 1.177 1.270	.550	2.08	3.71	1.053	.030	115.440	0.376 0.376 8.224	124.73 134.64 128.77	30.108 30.108 22.206	4.601 4.816 4.685
4	.250	3.594	3.930	3.660	–	.180	3.671	1.075	1.035	.506	1.446	3.60	1.418	.030	129.047	.72	132.39	29.764	4.386
5	.246	3.335	3.930	3.365	–	.180	3.671	1.084	1.037	.491	1.92	3.53	1.402	.030	119.733	.720	122.35	29.764	4.160
6	.241	3.071	3.930	3.120	–	.180	3.671	1.081	1.067	.471	2.145	3.45	1.382	.030	112.436	.720	112.41	29.764	3.725
8	.293	3.315	3.930	3.365	–	.180	3.671	1.089	1.033	.645	1.778	3.52	1.558	.030	116.755	.720	121.64	29.764	4.046
9	.237	3.340	3.930	3.362	–	.180	3.671	1.073	1.06	.455	1.61	3.53	1.365	.030	120.868	.720	123.24	29.764	4.082

Appendix A

HAM Mixer Dimensions

Mixer #	Type	SAR	Pen (%)	N_s	N_p	A_{mix} (in^2)	A_8 (in^2)	A_{89} (in^2)	A_{S89} (in^2)	W_{p8M} (in)	W_{p8E} (in)	W_{s8} (in)	W_{p89M} (in)	W_{p89E} (in)	W_{s89E} (in)	W_{s89M} (in)	W_T (in)	A_{ISN} (in)
3	Best Aero	2.501 (2.568)	100.0	20	18	64.724 (65.025)	25.878 (25.317)	27.287	30.376	.4333	–	.5821	.4611	–	.3890	.4431	9.643	37.437
4	Best Aero	2.502 (2.615)	92.5	20	18	64.724 (64.875)	25.870 (25.179)	27.292	30.849	.4669	–	.5474	.5011	–	.3544	.4068	9.643	37.432
8	Best Aero	2.897 (3.043)	92.5	20	18	64.724 (65.265)	22.341 (21.450)	23.416	34.674	.3868	–	.6239	.4159	–	.4280	.4842	9.643	41.308
10	Best Aero	2.502 (2.582)	85.0	20	18	64.724 (65.003)	25.874 (25.179)	27.298	31.361	.5158	–	.5056	.5507	–	.3116	.3617	9.643	37.426
21	NRA	2.8	100.0	20	20	64.724	23.116	31.9221	24.9208	.333	.185	.628	.479	.2505	–	.3840	9.643	32.802

Mix-er #	h_{gap} (in)	h_8 (in)	h_{S89} (in)	h_{P89} (in)	h_{89gap} (in)	h_{mix} (in)	CER local	CER area	L_{CER} (in)	β (deg.)	L_{mix} (in)	L_{89mix} (in)	t (in)	P_{p8} (in)	P_{p89} (in)	P_{mix89} (in)	P_{S89} (in)
3	.215	3.283	3.396	3.3615	.215	3.356	1.064	1.054	.3900	2.2	4.614	.5218	.030	121.358	0.86	121.892	31.430
4	.215	3.044	3.396	3.1191	.215	3.356	1.073	1.055	.4295	2.3	4.609	.5218	.030	112.520	0.86	112.270	31.430
8	.215	3.047	3.396	3.1191	.215	3.356	1.075	1.048	.4040	2.0	4.332	.5218	.030	112.527	0.86	113.011	31.430
10	.215	2.794	3.396	2.8666	.215	3.356	1.068	1.055	.4231	2.4	4.603	.5218	.030	103.257	0.86	103.64	31.430
21	.200	3.06	3.495	3.122	.200	3.356	1.492	1.381	.5778	8.0	4.4	.930	.050	141.686	12.406	124.544	7.68

Note

- Values inside paranthesies are measured quantities all other values are as designed.
  $A_{sin} = A_{mix} - A_8$

Appendix B, DSM Model

Drag Tares, June 1995, Original Test Section, M=0.245

Strut Drag Tare, Config 0.020						
% Bleed	**Mach**					
	0.11	**0.12**	**0.13**	**0.22**	**0.23**	**0.245**
0	92	93	94	97	95	96
80	77	82	83	100	88	89
90	78	81	84	99	87	90
100	79	80	85	98	86	91
Nozzle Drag Tare, Config 54.031, MAR=0.85						
% Bleed	**Mach**					
	0.11	**0.12**	**0.13**	**0.22**	**0.23**	**0.245**
0	136	137	138	139	140	141
80	118	121	124	127	130	133
90	119	122	125	128	131	134
100	120	123	126	129	132	135
Nozzle Drag Tare, Config 52.031, MAR=0.95						
% Bleed	**Mach**					
	0.11	**0.12**	**0.13**	**0.22**	**0.23**	**0.245**
0	160	161	162	163	164	165
80	142	145	148	151	154	157
90	143	146	149	152	155	158
100	144	147	150	153	156	159

Drag Tares, February 1996, New Test Section, M=0.32

Strut Drag Tare, Config 0.520									
% Bld	**Mach**								
	0.11	**0.12**	**0.13**	**0.22**	**0.23**	**0.245**	**0.31**	**0.32**	**0.33**
0	2081	2082	2083	2084	2085	2086	2087	2088	2089
80	2054	2057	2060	2063	2066	2069	2072	2075	2078
90	2055	2058	2061	2064	2067	2070	2073	2076	2079
100	2056	2059	2062	2065	2068	2071	2074	2077	2080
Nozzle Drag Tare, Config 52.532, MAR=0.95									
% Bld	**Mach**								
	0.11	**0.12**	**0.13**	**0.22**	**0.23**	**0.245**	**0.31**	**0.32**	**0.33**
0	2117	2118	2119	2120	2121	2122	2123	2324	2125
80	2090	2093	2096	2099	2102	2105	2108	2111	2114
90	2091	2094	2097	2100	2103	2106	2109	2112	2115
100	2092	2095	2098	2101	2104	2107	2110	2113	2116

Appendix B, DSM Model

Mixer 1, Isolated Mixer								
	Conf 100,506, Isolated Mixer				Conf 100.300, Isolated Mixer *			
	Cold Primary		Hot Primary		Cold Primary		Hot Primary	
NPR	M=0.0	0245	0.0	0.245	M=0.0	0.245	0.0	0.245
1.50	3625,3631							
2.00	3626,3632				102,113		107	
2.50	3627,3633				103,114		108	
3.00	3627,3634				104,115		109	
3.43	3628,3635				105,116		110	
4.00	3629,3636				106,117		111	

Note *: Instrumentation lines to flaps/sidewalls are attached.

Mixer 1, Hardwall, BLR Conf=1								
	Conf 152.101, MAR=0.95, Pen=100%				Conf 152.301, MAR=0.95, Pen=85%			
	Cold Primary		Hot Primary		Cold Primary		Hot Primary	
NPR	M=0.0	0.245	0.0	0.245	M=0.0	0.245	0.0	0.245
1.00						209 *		
1.51	310,312	318	324,325	336,337	166	172	178,179	190,191
1.99	311,313,355	319,350	326,327	338,339	167	173,204	180,181	192,193
2.48	314	320,351	328,329	340,341	168	174,205	182,183	194,195
2.96	315	321,352	330,331	342,343	169	175,206	184,185	196,197
3.20				344,345				198,199
3.43	316	322,353	332,333	346,347	170	176,207	186,187	200,201
4.00	317	323,354	334,335	348,349	171	177,208	188,189	202,203

Note *:Noise Floor, NPR=1.00

Mixer 1								
	Conf 152.303,Pen=85%,Mixer Exit Rakes				Conf 1152.100,Pen=100%,Rotated Mixer			
	Cold Primary		Hot Primary		Cold Primary		Hot Primary	
NPR	M=0.0	0.245	0.0	0.245	M=0.0	0.245	0.0	0.245
1.51			214			356		
1.99			214			357		
2.48	212		215	220		358		
2.96			216	221		359		
3.43	213		217	223		360		
4.00			218	219,224		361		

Mixer 1, 13mm SiC, BLR Conf=1								
	Conf 172.101, MAR=0.95, Pen=100%				Conf 172.301, MAR=0.95, Pen=85%			
	Cold Primary		Hot Primary		Cold Primary		Hot Primary	
NPR	M=0.0	0245	0.0	0.245	M=0.0	0.245	0.0	0.245
1.51	268	274	280,281	292,293	225	231	237,238	249,250
1.99	269	275,306	282,283	294,295	226	232,263	239,240	251,252
2.48	270	276,307	284,285	296,297	227	233,264	241,242	253,254
2.96	271	277,308	286,287	298,299	228	234,265	243,244	255,256
3.20				300,301				257,258
3.43	272	278,309	288,289	302,303	229	235,266	245,246	259,260
4.00	273	279	290,291	304,305	230	236,267	247,248	261,262

Appendix B, DSM Model

Mixer 2, Conf 251.240, Flow Tube						
	Cold Primary			Hot Primary		
NPR	M=0.0	0.12	0.245	0.0	0.12	0.245
1.51	869	875	881	886	892	898
1.99	870	876	882	887	893	899
2.48	871	877	883	888	894	900
2.96	872	878	884	889	895	901
3.43	873	879	885	890	896	902
4.00	868	874	880	891	897	903

Mixer 2, Isolated Mixer			
	Conf 200,506, Isolated Mixer	Conf 200.200, Isolated Mixer *	
	Cold Primary	Cold Primary	Hot Primary
NPR	M=0.0	M=0.0	0.0
1.50	2307,3613,3619		
2.00	3608,3614,3620	362,372	367
2.50	3609,3615,3621	363,373	368
3.00	3610,3616,3622	364,374	369
3.43	3611,3617,3623	365,375	370
4.00	3612,3618,3624	366,376	371

Note *: Instrumentation lines to flaps/sidewalls are attached.

Mixer 2, Hardwall								
	Conf 254.200, MAR=0.85, Pen=92.5%				Conf 253.200, MAR=0.90, Pen=92.5%			
	Cold Primary		Hot Primary		Cold Primary		Hot Primary	
NPR	M=0.0	0245	0.0	0.245	M=0.0	0.245	0.0	0.245
1.51			556,557	568,569			512,513	525,526
1.99	552	581	558,559	570,571	511	548	514,515	527,528
2.48	553	582	560,561	572,573	510	547	516,517	529,530
2.96	551,554	583	562,563	574,575	509	546	518,519	531,532
3.43	550,555	584	564,565	576,577	508,524	545	520,521	533,534
3.60								537,543
3.80								538,542
4.00	549	580	566,567	578,579	507	544	522	535,536 539,541
4.20								540

	Conf 252.200/252/201, MAR=0.95, Pen=92.5%						Conf 251.200, MAR=1.00, Pen=92.5%			
	Cold Primary		Hot Primary				Cold Pri		Hot Primary	
NPR	M=0.0	0245	0.0	0.12	0.18	0.245	0.0	0.245	0.0	0.245
1.51	392,377,385		397,398,765	774		409,410,782			590,591	602,603
1.99	393,378,386	425	399,400,766	775		411,412,783	586	623	592,593	604,605
2.37			767			784				
2.48	394,379,387	426	401,402,768	776	780	413,414,785	587	624	594,595	606,607
2.80										614622
2.96	395,380,388	427	403,404,769	777		415,416,786	588	625	596,597	608,609 615,621
3.20			770			787				616,620
3.43	396,381,389	428	405,406,771 772	778	781	417,418,788 789	589	626	598,599	610,611 617,619
3.60										618
4.00	391,382,390	424	407,408,422 423,773	779		419,420,421	585 628	627	600,601	612,613

Appendix B, DSM Model

Mixer 2, Hardwall							
	Conf 252.100 MAR=0.95, Pen=100%			Conf 252.300, MAR=0.95, Pen=85%			
	Cold Pri	Hot Primary		Cold Primary		Hot Primary	
NPR	M=0.0	0.0	0.245	M=0.0	0.245	0.0	0.245
1.00 *			658				
1.51		634,635	646,647,652			700	708
1.99	630	636,637	648,649,653	696	724	701	709
2.48	631	638,639	650,651,654	697	725	702,703	710,711
2.80							716,722
2.96	632	640,641	655	698	726	704	712,717,721
3.20							718,720
3.43	633	642,643	656	699	727	705,706	713,714,719
4.00	629	644,645	657	695	723	707	715

Note: Noise Floor

Mixer 2, 13mm SiC										
	Conf 273.200, MAR=0.90, Pen=92.5%				Conf 272.200, MAR=0.95, Pen=92.5%					
	Cold Primary		Hot Primary		Cold Primary		Hot Primary			
NPR	M=0	0245	0.0	0.245	M=0	0.245	0.0	0.12	0.18	0.245
1.51	472	501	477,478	489,490	430		435,436,800	809		447,448,817
1.99	473	502	479,480	491,492	431	467	437,438,801	810		449,450,818
2.37							802			819
2.48	474	503	481,482	493,494	432	468	439,440,803	811	815	451,452
2.96	475	504	483,484	495,496	433	469	441,442,804	812		453,454,459
3.10										460
3.20							805			461,820
3.30										462
3.43	476	505	485,486	497,498	434	470	443,444,806, 807	813	816	455,456,463 821
3.50										464
3.80										822
4.00	471	506	487,488	499,500	429	466	445,446,808	814		457,458

Mixer 2, 13mm SiC									
	Conf 272.100, MAR=0.95, Pen=100%				Conf 272.300, MAR=0.95, Pen=85%				
	Cold Primary		Hot Primary		Cold Primary		Hot Primary		
NPR	M=0.0	0245	0.0	0.245	M=0.0	0.245	0.0	0.12	0.245
1.00 *		658							
1.51			664	672			733		741
1.99	660	691	665	673	729	761	734		742
2.48	661	692	666,667	674	730	762	735,736	758	743,744
2.80				680					
2.96	662	693	668	676,681	731	763	737		745
3.20				682					749,757
3.43	663	694	669,670	677,678 683,689	732	764	738,739	759	746,747 750,756
3.60				684,688					751,755
3.80				685,687					752,754
4.00	659	690	671	679,686	728	760	740		748,753

* Note: Noise Floor

Config 473.546, Mixer 4, 13mm SiC, MAR=0.90, BLR Conf=6, Flow Tube							
	Mach Number, Cold Primary				Mach number, Cold Primary		
NPR	**0.0**	**0.245**	**0.32**	**NPR**	**0.0**	**0.245**	**0.32**
1.20	3193	3204	3215	2.00	3199	3210	3221
1.40	3194	3205	3216	2.40	3200	3211	3222
1.50	3195	3206	3217	2.80	3201	3212	3223
1.60	3196	3207	3218	3.20	3202	3213	3224
1.70	3197	3208	3219	3.60	3203	3214	3225
1.80	3198	3209	3220				

Mixer 4, Exit Survey/Isolated Mixer		
Config 453.506, Exit Survey, Mixer 4, Hardwall, MAR=0.90		Config 400.506, Isolated Mixer, No Fouling
NPR	**Mach=0.0, Hot Primary**	**Mach=0.0, Cold Primary**
1.50		3589,3595,3601
2.00		3590,3596,3602
2.50		3591,3597,3603
3.00		3593,3598,3604
3.43 *	3336, 3337, 3338, 3339, 3340, 3341, 3342, 3343	3594,3599,3605
4.00	3344, 3345, 3346, 3347, 3348, 3349, 3350, 3351	3592,3600,3606

Note *: TTPri=1490°R (instead of 1551°R)

Mixer 4, Hardwall, BLR Conf=6								
	Conf 453.506, MAR=0.90				Conf 452.506, MAR=0.95			
	Cold Primary		Hot Primary		Cold Primary		Hot Primary	
NPR	**M=0.0**	**0.32**	**0.0**	**0.32**	**M=0.0**	**0.32**	**0.0**	**0.32**
1.51			3310	3318			3280	3288
1.99	3331	3326	3311	3319	3301*,3307	3291	3281	3289
2.37			3312	3320			3282	3290
2.48	3332	3327	3313	3321	3302*,3308	3297	3283	3292
2.96	3333	3328	3314	3322	3303*,3309	3298	3284	3293
3.25			3315	3323			3285	3294
3.43	3334	3329	3316	3324	3304*,3305	3299	3286	3295
4.00	3335	3330	3317	3325	3306	3300	3287	3296

Mixer 4, 13mm SiC, BLR Conf=6								
	Conf 473.506, MAR=0.90				Conf 472.506, MAR=0.95			
	Cold Primary		Hot Primary		Cold Primary		Hot Primary	
NPR	**M=0.0**	**0.32**	**0.0**	**0.32**	**M=0.0**	**0.32**	**0.0**	**0.32**
1.51			3231	3239			3257	3265
1.99	3226	3247	3232	3240	3252	3271	3258	3266
2.37			3233	3241			3259	3267
2.48	3227	3248	3234	3242	3253	3272	3260	3268,3276
2.96	3228	3249	3235	3243	3254	3273	3261	3269
3.25			3236	3244			3262	3270,3277
3.43	3229	3250	3237	3245	3255	3274	3263	3278
4.00	3230	3251	3238	3246	3256	3275	3264	6579

Note *: Vacuum left on

Mixer 5, Isolated Primary				
Config 500.000, Mixer 5, Isolated Primary (Fouled Balance)			Config 500.506, Mixer 5, Isolated Primary	
	Cold Primary	Hot Primary		Mach number, Cold Primary
NPR	M=0.0	M=0	NPR	0.0
1.51	905, 917	910	1.51	3535,3541,3547
1.99	906, 918	911	1.99	3536,3542,3548
2.48	907, 919	912	2.48	3537,3543,3549
2.96			2.96	3538,3544,3550
3.43	908, 920	913	3.43	3539,3545,3551
4.00	904, 916	914	3.60	3540,3546,3552

Config 553.046 , Mixer , 13mm SiC, Flow Tube – See Note									
	Mach Number, Cold Primary					Mach number, Cold Primary			
NPR	0.0	0.12	0.245	0.32	NPR	0.0	0.12	0.245	0.32
1.20	2208		2219	2230	2.20	2191,2202			
1.40	2177,2182,2198	2209	2220	2231	2.40	2203	2215	2226	2237
1.50		2210	2221	2232	2.60	2204			
1.60	2178,2183,2188, 2199	2211	2222	2233	2.80	2186,2205	2216	2227	2238
1.70		2212	2223	2234	3.00	2181,2206			
1.80	2179,2184,2189, 2200	2213	2224	2235	3.20	2207	2217	2228	2239
2.00	2180,2185,2190, 2201	2214	2225	2236	3.60		2218	2229	2240

Config 553.056 , Mixer , 13mm SiC, Flow Tube With Covered Inlets	
	Mach Number, Cold Primary
NPR	0.0
1.40	2192
1.60	2193
2.00	2194
2.50	2195
3.00	2196
3.50	2197

Note: runs 2177–2181, Aexit=52 in**2
runs 2182–2197, Aexit=60 in**2
runs 2198–2240, Aexit=72 in**2

Mixer 5, Hardwall, Balance Shifted Data									
	Conf 552.000, MAR=0.95					Conf 551.000, MAR=1.00			
	Cold Primary		Hot Primary			Cold Primary		Hot Primary	
NPR	M=0.0	0.245	0.0	0.12	0.245	M=0.0	0.245	0.0	0.245
1.51	983		988		970	1179		1170	1184
1.99	984	977	989		971	1180		1171	1185
2.48	985	978	990,991	996	972,998	1181	1192	1172,1173	1186,1187
2.96	986	979	992		973	1182		1174	1188
3.20					999				
3.43	987	980,981*	993,994	997	974,1000	1183	1193	1175,1176	1189,1190
4.00	982	976	995		975	1178		1177	1191

Mixer 5, Hardwall, Balance Shifted Data								
	Conf 554.006, MAR=0.85				Conf 553.006, MAR=0.90			
	Cold Primary		Hot Primary		Cold Primary		Hot Primary	
NPR	M=0.0	0.245	0.0	0.245	M=0.0	0.245	0.0	0.245
1.51	1088		1093	1101	1049		1054	1062
1.99	1089	1083	1094	1102	1050	1078	1055	1063
2.48	1090	1084	1095,1096	1103,1104	1051	1079	1056,1057	1064,1065
2.96	1091	1085	1097	1105	1052	1080	1058	1066
3.43	1092	1086	1098,1099	1106,1107	1053	1081	1059,1060	1067,1068
3.50								1070
3.60								1071,1076
3.70								1072
3.80								1073,1075
3.90								1074
4.00	1087	1082	1100	1108	1048	1077	1061	1069

Note: Run 981, Oil Flow Run – No Aerothermal or Acoustic Data Taken

Mixer 5, 13mm SiC, BLR Conf=0, Balance Shifted Data								
	Conf 574.000, MAR=0.85				Conf 573.000, MAR=0.90			
	Cold Primary		Hot Primary		Cold Primary		Hot Primary	
NPR	M=0.0	0.245	0.0	0.245	M=0.0	0.245	0.0	0.245
1.51	1110		1115	1123	1015		1020	1028
1.99	1111	1132	1116	1124	1016	1044	1021	1.29
2.48	1112	1133	1117,1118	1125,1126	1017	1045	1022,1023	1030,1031
2.96	1113	1134	1119	1127	1018	1046	1024	1032
3.43	1114	1135	1120,1121	1128,1129	1019	1047	1025,1026	1033,1034
3.50								1036
3.60								1037,1042
3.70								1038
3.80								1039,1041
3.90								1040
4.00	1109	1131	1122	1130	1014	1043	1027	1035
	Conf 572.000, MAR=0.95				Conf 571.000, MAR=1.00			
	Cold Primary		Hot Primary		Cold Primary		Hot Primary	
NPR	M=0.0	0.245	0.0	0.245	M=0.0	0.245	0.0	0.245
1.51	923	951	928	934	1153		1144	1136
1.99	924	952	947	935	1154	1166	1145	1137
2.48	925	953	932	929,936	1155	1167	1147	1138,1139
2.60								1158,1164
2.80								1159,1163
2.96	926	954	948	937	1156	1168	1148	1140,1160 1162
3.20				940,946				1161
3.43	927	955	931,933	930,938	1157	1169	1149,1150	1141,1142
3.60				941,945				
3.80				942,944				
4.00	922	950	949	939,943	1152	1165	1151	1143

Mixer 5, Hardwall, Balance Data Ok						
	Conf 553.006/553.506, MAR=0.90					
	Cold Primary			Hot Primary		
NPR	M=0.0	0.245	0.32	0.0	0.245	0.32
1.00 *	2163	2247,2165	2166			
1.51	1660			1665,1672	1678,2241	2288
1.99	1661	1697	2297	1666,1667,1673	1679,1692,2242	2289
2.37					2171	2167
2.48	1662,1688	1686,1698	2298	1668,1674,1690 2175	1680,1684,2243 2172	2168,2290,2291
2.96	1663	1699	2299	1669,1675	1681,1693,2244	2292
3.25					2173	2169
3.43	1664,1689	1687,1700	2300	1670,1676,1691 2176	1682,1694,2245 2174	2170,2293,2294
4.00	1659	1696	2296	1671,1677	1683,1695,2246	2295

Mixer 5, Hardwall, Balance Data Ok				
	Conf 552.006, MAR=0.95			
	Cold Primary		Hot Primary	
NPR	M=0.0	0.245	0.0	0.245
1.51	1499		1504,1505	1518,1519
1.99	1500	1534	1262,1506	1520,1528
2.48	1501,1514,1538	1535	1263,1507,1508,1516,1540	1521,1522,1529
2.96	1502	1536	1264,1509	1523,1530
3.43	1503,1515,1539	1537	1265,1510.1511,1517,1541	1524,1525,1531
4.00	1498	1533	1266,1512,1513	1526,1527,1532

Note: * Noise Floor

Mixer 5, Treated – Balance Data OK							
Conf 573.506/573.006, MAR=0.90							
	Cold Primary			Hot Primary			
NPR	M=0.0	0.245	0.32	0.0	0.12	0.245	0.32
1.51						2266	2272
1.99		2284	2279	1194,1201,1220,1226	1236	1223,1241,2267	2273
2.37						1242	
2.48	1211	1213,2285	2280	1197,1204,1217,1229 1260,1261	1237.	1215,1244,1243(1) 1245(2),1248, 1246(3),2268	2274
2.96		2286	2281	1198,1205,1218,1230	1238	1224,1247,2269	2275
3.20				1199,1206,1207,1231		1249	
3.25						1250	
3.35				1209,1233		1251	
3.43	1212	1214,2287	2282	1221,1234	1239	1216,1252,1253, 1254,1259,1255(1) 1256(2),1257(3), 2270	2276
4.00		2283	2278	1222,1235	1240	1225,1258,2271	2277

(1) Temp Variation + 200°, (2) Temp Variation –200°, (3) Temp Variation –400°

Mixer 5, Treated Foam Metal – Balance Data OK								
	Conf 543.006, MAR=0.90				Conf 542.006, MAR=0.95			
	Cold Primary		Hot Primary		Cold Primary		Hot Primary	
NPR	M=0.0	0.245	0.0	0.245	M=0.0	0.245	0.0	0.245
1.51	1602		1607	1613	1563		1568	1574
1.99	1603	1620	1608	1614	1564,1586	1581,1598	1569,1590	1575,1595
2.48	1604,1630	1621,1624	1609,1628	1615,1626	1565,1587	1582,1599	1570,1591	1576,1596
2.96	1605	1622	1610	1616	1566,1588	1583	1571,1592	1577
3.43	1606,1631	1623,1625	1611,1629	1617,1627	1567,1589	1584,1600	1572,1593	1578,1597
4.00	1601	1619	1612	1618	1562,1585	1580	1573,1594	1579

Mixer 5, Treated 7mm SiC, and Forward HW/Aft 13mm SiC, Balance Data OK								
	Conf 563.006, MAR=0.90				Conf 593.006, MAR=0.90			
	Cold Primary		Hot Primary		Cold Primary		Hot Primary	
NPR	M=0.0	0.245	0.0	0.245	M=0.0	0.245	0.0	0.245
1.51	1633		1638	1644	1702		1707	1713
1.99	1634	1651	1639	1645	1703	1720	1708,1724	1714
2.48	1635	1652	1640,1657	1646,1655	1704	1721,1729	1709,1725	1715,1731
2.96	1636	1653	1641	1647	1705	1722	1710,1726	1716
3.43	1637	1654	1642,1658	1648,1656	1706	1723,1730	1711,1727	1717,1732
4.00	1632	1650	1643	1649	1701	1719	1712,1728	1718

Mixer 5, Treated – SDOF, Balance Data Ok				
	Conf 583.006, MAR=0.90, SDOF Liner			
	Cold Primary		Hot Primary	
NPR	M=0.0	0.245	0.0	0.245
1.51	1734		1745	1739,1751
1.99	1735	1761	1746,1765	1740,1752,1757
2.48	1736	1744,1762	1747,1766	1741,1753,1758
2.96	1737	1763	1748,1767	1742,1754
3.43	1738	1764	1749,1768	1743,1755,1759
4.00	1733	1760	1750,1769	1756

Appendix B, DSM Model

Mixer Exit Rakes Hardwall					
	Conf 552.004, MAR=0.95, Mixer Exit Rake, Hardwall				Conf 552.005, Oil Flow Mixer Exit Rake & BL Rake, MAR=0.95 , HW
	Cold Primary		Hot Primary		Cold Primary
NPR	**M=0.0**	**0245**	**0.0**	**0.245**	**0245**
1.99	957	966			1005,1012*
2.48	958	967	961	963	1006,1011*
2.96	959	968			1007
3.43	960	969	962	964	(1001,1002,1003,1004)**,1009,1010***
4.00	956	965			1008

Note: * Fairing Boundary Layer Suction = 80% (Normal Suction =100%
** No Oil, Fairing BL Suction Varied run 1001=0%, 1002=50%, 1003=80%, 1004=100%
*** Fairing BL Suction=50%

Config 573.566, Exit Survey, Mixer 5, 13mm SiC, MAR=0.90, Pitot Probe	
NPR	**Mach=0.0, Hot Primary**
2.48	2304,2305,2306,2307,2308,2309,2310,2311,2312,2313,2314
3.43	2302
	Mach=0.12, Hot Primary
3.43	2303
Config 573.576, Exit Survey, Mixer 5, 13mm SiC, MAR=0.90, Pratt 5 Hole (No TC)	
NPR	**Mach=0.0, Hot Primary**
2.48	2324
2.96	2325
3.43	2301,2315,2316,2317,2318,2319,2326
Config 573.586, Exit Survey, Mixer 5, 13mm SiC, MAR=0.90, Kiel Probe W TC	
NPR	**Mach=0.0, Hot Primary**
2.96	2263
3.27	2264
3.43	2253,2254,2257,2259,2261,2262

Config 673.546, Mixer 4, 13mm SiC, MAR=0.90, BLR Conf=6, Flow Tube							
Mach Number, Cold Primary				Mach number, Cold Primary			
NPR	0.0	0.245	0.32	NPR	0.0	0.245	0.32
1.20	3352	3364	3376	2.00	3358	3370	3382
1.40	3353	3365	3377	2.20	3359	3371	3383
1.50	3354	3366	3378	2.40	3360	3372	3384
1.60	3355	3367	3379	2.60	3361	3373	3385
1.70	3356	3368	3380	2.80	3362	3374	3386
1.80	3357	3369	3381	3.00	3363	3375	3387

Mixer 6, Hardwall, BLR Conf=6								
	Conf 653.506, MAR=0.90				Conf 652.506, MAR=0.95			
	Cold Primary		Hot Primary		Cold Primary		Hot Primary	
NPR	M=0.0	0.32	0.0	0.32	M=0.0	0.32	0.0	0.32
1.51			3483	3475			3449	3455
1.99	3491	3496	3484	3476	3470	3462	3450	3456
2.37			3485	3477			3451	3457
2.48	3492	3497	3486	3478	3471	3463	3452	3458,3467
2.96	3493	3498	3487	3479	3472	3464	3453	3459
3.25			3488	3480			3454	3460
3.43	3494	3499	3489	3481	3473	3465	3446,3447	3461,3468
4.00	3495		3490	3482	3474	3466	3448	3469
Mixer 6, 13mm SiC, BLR Conf=6								
	Conf 673.506, MAR=0.90				Conf 672.506, MAR=0.95			
	Cold Primary		Hot Primary		Cold Primary		Hot Primary	
NPR	M=0.0	0.32	0.0	0.32	M=0.0	0.32	0.0	0.32
1.51			3406	3398			3424,3426	3416
1.99	3388	3393	3407	3399	3441	3436	3425,3427	3417
2.37			3408	3400			3428	3418
2.48	3389	3394	3409	3401,3414	3442	3437	3429	3419,3434
2.96	3390	3395	3410	3402	3443	3438	3430	3420
3.25			3411	3403			3431	3421
3.43	3391	3396	3412	3404,3415	3444	3439	3432	3422,3435
4.00	3392	3397	3413	3405	3445	3440	3433	3423

Mixer 6, Exit Survey/Isolated Mixer		
Config 653.576, Exit Survey, Mixer 6, Hardwall, MAR=0.90,		Config 600.506, Isolated Mixer, No Fouling
NPR	Mach=0.0, Hot Primary	Mach=0.0, Hot Primary
1.50		3517,3523,3529
2.00		3518,3524,3530
2.50	3509, 3510, 3511, 3512, 3513, 3514, 3515, 3516	3519,3525,3531
3.00		3520,3526,3532
3.43	3501, 3502, 3503, 3514, 3505, 3506, 3507, 3508	3521,3527,3533
4.00		3522,3528,3534

Config 853.046, Mixer 8, Hardwall, MAR=0.90, BLR Conf=6, Flow Tube				
	Cold Primary		Hot Primary	
NPR	0.0	0.245	0.0	0.245
1.40	1937,2015	1960,1982	1949,2004	1971,1993
1.60	19382016	1961,1983	1950,2005	1972,1994
1.80	1939,2017	1962,1984	1951,2006	1973,1995
2.00	1940,1948,2018	1963,1985	1952,2007	1974,1996
2.20	1941,2019	1964,1986	1953,2008	1975,1997
2.40	1942,2020	1965,1987	1954,2009	1976,1998
2.60	1943,2021	1966,1988	1955,2010	1977,1999
2.80	1944,2022	1967,1989	1956,2011	1978,2000
3.00	1945,2023	1968,1990	1957,2012	1979,2001
3.20	1946,2024	1969,1991	1958,2013	1980,2002
3.40	1947,2025	1970,1992	1959,2014	1981,2003

Mixer 8 Isolated Nozzle			
	Conf 800.000, Balanced Fouled		Conf 800.506, Balance OK
NPR	Cold Primary, M=0.0	Hot Primary, M=0.0	Cold Primary, M=0.0
1.51	1771,1783	1776	3571,3579,3585,3588
1.99	1772,1784	1777	3572,3580,3586
2.48	1773,1785	1778	3573,3581,3587
2.96	1774,1786	1779	3574,3582,3588
3.43	1775	1780	3575,3583
4.00		1781	3576,3584

Mixer 8, Hardwall, BLR Conf=6								
	Conf 853.006, MAR=0.90				Conf 852.006, MAR=0.95			
	Cold Primary		Hot Primary		Cold Primary		Hot Primary	
NPR	M=0.0	0.245	0.0	0.245	M=0.0	0.245	0.0	0.245
1.51	1863,1871		1867,1875	1884	1903		1907	1915
1.99	1864,1872	1893	1868,1883	1885	1904	1924	1908	1916
2.48	1865,1873	1894,1900	1869,1877, 1878	1886,1887, 1896	1905,1927	1925,1935	1909,1910, 1929	1917,1918
2.96	1866,1874	1895	1879	1888	1906	1926	1911	1919
3.20				1897				1932
3.30				1898				1933
3.43	1862,1870	1892,1901	1880,1881	1889,1890, 1899	1902,1928	1923,1936	1912,1913, 1930	1920,1921, 1934
4.00			1882	1891			1914	1922

Mixer 8 13mm SiC, BLR Conf=6								
	Conf 873.06, MAR=0.90				Conf 872.006, MAR=0.95			
	Cold Primary		Hot Primary		Cold Primary		Hot Primary	
NPR	M=0.0	0.245	0.0	0.245	M=0.0	0.245	0.0	0.245
1.51	1788		1792	1798	1828		1832	1840
1.99	1789,1808	1805	1793,1812	1799,1817	1829	1849	1833	1841
2.48	1790,1809	1806,1825	1794,1813, 1824	1800,1818	1830,1852	1850,1860	1834,1835, 1854	1842,1843, 1856
2.96	1791,1810	1807	1795,1814	1801,1819	1831	1851	1836	1844
3.43	1787,1811	1804,1826	1796,1815	1802,1820	1827,1853	1848,1861	1837,1838, 1855	1845,1846, 1857
3.60				1821				1858
3.80				1822				1859
4.00			1797,1816	1803,1823			1839	1847

Appendix B, DSM Model

Mixer 9, Isolated Primary				
Config 900.500, Isolated Primary (Fouled Balance)			**Config 900.506, Isolated Primary** Balance Ok	
	Cold Primary	Hot Primary		Mach number, Cold Primary
NPR	M=0.0	M=0	NPR	0.0
1.51	2327,2339	2333	1.51	3553,3559,3565
1.99	2328,2340	2334	1.99	3554,3560,3566
2.48	2329,2341	2335	2.48	3555,3561,3567
2.96	2330,2342	2336	2.96	3556,3562,3568
3.43	2331,2343	2337	3.43	3557,3563,3569
4.00	2332,2344	2338	3.60	3558,3564,3570

Config 973.546 , Mixer 9, 13mm SiC, MAR=0.90, Flow Tube									
	Mach Number, Cold Primary					Mach number, Cold Primary			
NPR	0.0	0.12	0.245	0.32	NPR	0.0	0.12	0.245	0.32
1.20	2345	2356	2367	2378	2.00	2351	2362	2373	2384
1.40	2346	2357	2368	2379	2.40	2352	2363	2374	2385
1.50	2347	2358	2369	2380	2.80	2353	2364	2375	2386
1.60	2348	2359	2370	2381	3.20	2354	2365	2376	2387
1.70	2349	2360	2371	2382	3.60	2355	2366	2377	2388
1.80	2350	2361	2372	2383					

Mixer 9, Hardwall, 1 Balance Scan Data						
	Conf 953.506, MAR=0.90					
	Cold Primary			Hot Primary		
NPR	M=0.0	0.245	0.32	0.0	0.245	0.32
1.51	2550	2568	2580	2556	2562	2574
1.99	2551	2569	2581	2557	2563	2575
2.48	2552	2570	2582	2558	2564	2576
2.96	2553	2571	2583	2559	2565	2577
3.43	2554	2572	2584	2560	2566	2578
4.00	2555	2573	2585	2561	2567	2579
	Conf 952.506, MAR=0.95					
1.51	2516			2522	2530	2540
1.99	2517			2523	2531	2541
2.37				2524	2532	2542
2.48	2518	2538		2525	2533	2543
2.96	2519			2526	2534	2544
3.25				2527	2535	2545
3.43	2520	2539		2528	2536	2546
4.00	2521			2529	2537	2547

Appendix B, DSM Model

Mixer 9, 13mm SiC, 1 Balance Scan Data						
	Conf 973.506, MAR=0.90					
	Cold Primary			Hot Primary		
NPR	M=0.0	0.245	0.32	0.0	0.245	0.32
1.00 *	2389	2391	2392			
1.51	2396,2414	2432	2444	2402,2420	2408,2426	2438
1.99	2397,2415	2433	2445	2403,2421	2409,2427	2439
2.37						
2.48	2398,2416	2434	2446	2404,2422,2450	2410,2428	2440
2.96	2399,2417	2435	2447	2405,2423	2411,2429	2441
3.25						
3.43	2400,2418	2436	2448	2406,2424	2412,2430	2442
4.00	2401,2419	2437	2449	2407,2425	2413,2431	2443
	Conf 972.506, MAR=0.95					
	Cold Primary			Hot Primary		
NPR	M=0.0	0.245	0.32	0.0	0.245	0.32
1.51	2451,2483	2469		2457,2591	2463,2599	2475,2617
1.99	2452,2586	2470,2607	2612	2458,2592	2464,2600	2476,2618
2.37				2593	2601	2619
2.48	2453,2587	2471,2608	2481,2613	2459,2594	2465,2602	2477,2620
2.96	2454,2588	2472,2609	2614	2460,2495	2466,2603	2478,2621
3.25				2596	2604	2622
3.43	2455,2589	2473,2610	2482,2615	2461,2597	2467,2605	2479,2623
4.00	2456,2590	2474,2611	2616	2462,2598	2468,2606	2480,2624
	Conf 971.506, MAR=1.00					
	Cold Primary			Hot Primary		
NPR	M=0.0	0.245	0.32	0.0	0.245	0.32
1.00 *		2495,2496,2497	2498,2499			
1.51				2489	2500	2508
1.99	2484			2490	2501	2509
2.48	2485	2506	2514	2491	2502	2510
2.96	2486			2492	2503	2511
3.43	2487	2507	2515		2504	2512
4.00	2488				2505	2513

Conf 972.606, MAR=0.95,Inlet Lip, 1 Balance Scan Data			
	Cold	Hot Primary	
NPR	M=0.32	M=0.0	M=0.32
1.99	2630		
2.48	2631	2625	2627
2.99	2632		2628
3.43	2633	2626	2629
4.00	2634		

* Noise Floor

Appendix B, DSM Model

Mixer 9, Hardwall, 10 Balance Scan Data (Normal)						
	Conf 953.506, MAR=0.90					
	Cold Primary			Hot Primary		
NPR	M=0.0	0.245	0.32	0.0	0.245	0.32
1.00 *	2742	2743				
1.99				2746	2754	2762
2.37				2747	2755	2763
2.48	2744		2769	2748	2756	2764
2.96				2749	2757	2765
3.25				2750	2758	2766
3.43	2745		2770	2751,2752	2759,2760	2767
4.00				2753	2761	2768
	Conf 952.506, MAR=0.95					
1.99				2773,2780	2785,2797	2790,2802
2.37						
2.48	2771,2778		2795	2774,2781	2786,2798	2791,2803
2.96				2775,2782	2787,2799	2792,2804
3.25						
3.43	2772,2779		2796	2776,2783	2788,2800	2793,2805
4.00				2777,2784	2789,2801	2794,2806

Mixer 9, 13mm SiC, 10 Balance Scan Data (Normal)						
	Conf 973.506, MAR=0.90					
	Cold Primary			Hot Primary		
NPR	M=0.0	0.245	0.32	0.0	0.245	0.32
1.00 *	2699	2700	2701,2723,2730			
1.99				2704	2711	2718,2731
2.37				2705	2712	2719,2724,2732
2.48	2702		2721,2722	2706	2713	2720,2725,2733
2.96				2707	2714	2726,2734
3.25				2708	2715	2727,2735,(1)2738 (2) 2739
3.43	2703		2740,2741	2709	2716	27282736
4.00				2710	2717	27292737
	Conf 972.506, MAR=0.95					
	Cold Primary			Hot Primary		
NPR	M=0.0	0.245	0.32	0.0	0.245	0.32
1.51						
1.99				2668,2688	2674	2680
2.37				2669	2675	2681
2.48				2670	2676	2682
2.96						
3.25				2671	2677	2683
3.43				2672,2687	2678	2684
4.00				2673	2679	2685

* Noise Floor

(1) Temp Varation +150° (2) Temp Variation −150°

Appendix B, DSM Model

Mixer 9, Treated SDOF/Eggcrate/Inlet Lip 10 Scan Data (Normal)												
	SDOF, Conf 982.006, MAR=0.95						**Eggcrate Conf 932.006, MAR=0.95**			**Inlet Lip Conf 972.606, MAR=0.95**		
	Cold Primary			Hot Primary			Hot Primary			Cold	Hot Primary	
NPR	M=0	0.245	0.32	0.0	0.245	0.32	0.0	0.245	0.32	0.32	0.0	0.32
1.51				2640	2646	2657						
1.99	2635	2652	2663	2641	2647	2658				2689		
2.48	2636	2653	2664	2642	2648	2659	2807	2810	2813	2690	2694	2696
2.96	2637	2654	2665	2643	2649	2660				2691		2697
3.25							2808	2811				
3.43	2638	2655	2666	2644	2650	2661	2809	2812		2692	2695	2698
4.00	2639	2656	2667	2645	2651	2662				2693		

Mixer 9			
Survey – Nozzle, Pratt 5 Hole W TC, Mach=0.0			
Config	**NPR**	**Ttp °R**	**Runs**
973.576	2.48	1291	2854,2855,2856,2857,2858,2859,2860,2861
973.576	3.25	1482	2846,2847,2848,2849,2950,2851,2852,2853
973.576	3.48	Amb	2862,2683,2864,2865,2866,2867,2868,2869
973.576	3.48	1551	2838,2839,2840,2841,2842,2843,2844,2845
972.576	2.48	1291	2830,2831,2832,2833,2834,2835,2836,2837
972.576	3.25	1482	2822,2823,2824,2825,2826,2827,2828,2829
972.576	3.43	1551	2814,2815,2816,2817,2818,2819,2820,2821
953.576	2.48	1291	2888,2889,2890,2891,2892,2893,2894,2895
953.576	3.25	1482	2879,2880,2881,2882,2883,2884,2885,2886
953.576	3.43	Ambient	2904,2905,2906,2907,2908,2909,2910,2911
953.576	3.43	1000	2896,2897,2898,2899,2900,2901,2902,2903
953.576	3.43	1551	2871,2872,2873,2874,2875,2876,2877,2878
952.576	2.48	1291	2928,2929,2930,2931,2932,2933,2934,2935
952.576	3.25	1482	2920,2921,2922,2923,2924,2925,2926,2927
952.576	3.43	1551	2912,2913,2914,2915,2916,2917,2918,2919
Survey – Duct MStat 8.10, Pratt 5 Hole W TC, Mach=0.0			
973.576	3.43	Ambient	3021,3022,3023,3024,3025,3026,3027,3028,3029,3030,3031,3032,3033,3034
973.576	3.43	1551	3002,3003,3004,3005,3006,3007,3008,3009,3010,3011,3012,3013,3014,3015, 3016,3017,3018,3019,3020
972.576	3.43	1551	3035,3036,3037,3038,3039,3040,3041,3042,3043,3044,3045,3046,3047,3048, 3049,3050,3051,3052,3053
953.576	3.43	Ambient	2979,2980,2981,2982,2983,2984,2985,2986,2987,2988,2989,2990,2991,2992
953.576	3.25	1000	2974,2975,2976,2977,2978,2993,2994,2995,2996,2997,2998,2999,3000,3001
953.576	3.43	1551	2955,2956,2957,2958,2959,2960,2961,2962,2963,2964,2965,2966,2967,2968 2969,2970,2971,2972,2973
952.576	3.43	1551	2936,2937,2938,2939,2940,2941,2942,2943,2944,2945,2946,2947,2948,2949 2950,2951,2952,2953,2954
Survey – Duct MStat 4.05, Pratt 5 Hole W TC, Mach=0.0			
973.576	3.43	Ambient	3080,3081,3082,3083,3084,3085,3086,3087,3088,3089,3090,3091,3092,3093
973.576	3.43	1551	3073,3074,3075,3076,3077,3078,3079,3094,3095,3096,3097,3098,3099,3100 3101
972.576	3.43	1551	3054,3055,3056,3057,3058,3059,3060,3061,3062,3063,3064,3065,3066,3067 3068,3069,3070,3071,3072
953.576	3.43	1551	3104,3105,3106,3107,3108,3109,3110,3111,3112,3113,3114,3115,3116,3117
952.576	3.43	1551	3164,3165,3166,3167,3168,3169,3170,3171,3172,3173,3174,3175,3175,3177
Survey – Duct MStat 2.00, Pratt 5 Hole W TC, Mach=0.0			
972.576	3.43	1551	3178,3179,3180,3181,3182,3183,3184,3185,3186,3187,3188,3189,3190,3191
Survey – Duct MStat 0.50, Pratt 5 Hole W TC, Mach=0.0			
Config	**NPR**	**Ttp °R**	**Runs ***(loose probe)*****
953.576	3.43	1551	3146,3147,3148,3149,3150,3151,3152,3153,3154,3155,3156,3157,3158,3159
952.576	3.43	1551	3160,3161,3162

Appendix B, HAM Model

Reference Mixers, ASME/Cubic				
NPR	Conf 100.00, Cubic		Conf 2000.000, ASME	
			Hot Primary	
	Cold, M=0.0	Hot, M=0.0	0.0	0.32
1.00				830 *
1.51	18,802,808	1,9,788,796	814	822
1.99	19,25,803,809	2,10,789,797	815	823
2.37		3,11,790,	816	824
2.48	20,804,810	4,12,791,798	817	825
2.96	21,26,805,811	5,13,792,799	818	826
3.25		6,14,793	819	827
3.43	22,806,812	7,15,794,800	820	828
4.00	23,27,807,813	8,16,795,801	821	829
4.50	24,28	17		

Note: * Noise Floor

Strut Drag Tare Runs, Config 0.020						
%Bleed	Mach					
	0.23	0.245	0.25	0.31	0.32	0.33
0	83	84	85	86	87	88
70	29	33	37	41	45	49
80	30	34	38	42	46	50
90	31	35	39	43	47	51
100	32	36	40	44	48	52

Nozzle Drag Tare Runs, Config 2132.036						
%Bleed	Mach					
	0.23	0.245	0.25	0.31	0.32	0.33
0	83	84	85	86	87	88
70	59	63	67	71	75	79
80	60	64	68	72	76	80
90	61	65	69	73	77	81
100	62	66	70	74	78	82

Mixer 3, Config 300.00, Isolated Mixer	
	Mach Number, Cold Primary
NPR	0.0
1.53	734,740,746
1.99	735,741,747
2.48	736,742,748
2.96	737,743,749
3.43	738,744,750
4.00	739,745,751

Mixer 3, Pen=100% ,BLR Conf=6								
	Conf 312.006, Hardwall MAR=0.95				Conf 322.006, 13mm SiC, MAR=0.95			
	Cold Primary		Hot Primary		Cold Primary		Hot Primary	
NPR	M=0.0	0.32	0.0	0.32	M=0.0	0.32	0.0	0.32
1.51			507	499			485	477
1.99	495		508	500	473		486	478
2.37			509	501			487	479
2.48	496	515	510	502	474	493	488	480
2.96	497		511	503	475		489	481
3.25			512	504			490	482
3.43	498	516	513	505	476	494	491	483
4.00			514	506 *			492	484

* Note: Possible Primary Airflow Problem (Trouble holding condition)

Mixer 4, SAR=2.5, Pen=92.5%, BLR Conf=6, MAR=0.95, Hardwall								
	Conf 412.006, 120" Flap				Conf 452.006, 160" Flap			
	Cold Primary		Hot Primary		Cold Primary		Hot Primary	
NPR	M=0.0	0.32	0.0	0.32	M=0.0	0.32	0.0	0.32
1.51			247	255			365	373
1.99	242		248	256,258	360		366	374
2.37			249	257,259			367	375
2.48	243	267	250	260	361	382	368	376
2.96	244		251	261	362	383	369	377
3.25			252	262			370	378
3.43	245	268	253	263	363	384	371	379
4.00	246		254	266,264*,265**	364	385	372	380

Note: * Run 264, 1091°R – 151°
** Run 265, 1091°R + 149°

Mixer 4, SAR=2.5, Pen=92.5%, BLR Conf=6, MAR=0.95, 13mm SiC								
	Conf 422.006, 120" Flap				Conf 472.006, 160" Flap			
	Cold Primary		Hot Primary		Cold Primary		Hot Primary	
NPR	M=0.0	0.32	0.0	0.32	M=0.0	0.32	0.0	0.32
1.51			181	189			309***,319	299
1.99	176	199	182	190	296		310***,320	300
2.37			183	191			311***,321	301
2.48	177	200	184	192	297	324	312***,322	302
2.96	178	201	185	193	298		313***,323	303
3.25			186	194			314	304
3.43	179	202	187	195,196*,197**	307***	325	315	305
4.00	180	203	188	198	308***		316	306

Note: * Run 196, 1091°R – 151°
** Run 197, 1091°R + 149°
*** Runs 307–313, Tunnel Vacuum was left on by mistake.

Mixer 4, SAR=2.5, Pen=92.5%, BLR Conf=6, MAR=0.90, 13mm SiC				
	Conf 473.006, 160" Flap			
	Cold Primary		Hot Primary	
NPR	M=0.0	0.32	0.0	0.32
1.51			274	282
1.99	269	291	275	283
2.37			276	284
2.48	270	292	277	285
2.96	271	293	278	286
3.25			279	287
3.43	272	294	280	288
4.00	273	295	281	289

Mixer 4, SAR=2.5, Pen=92.5%, BLR Conf=6, MAR=0.95, 13mm SiC, With Chevrons								
	Conf 422.106, 120" Flap				Conf 472.106, 160" Flap			
	Cold Primary		Hot Primary		Cold Primary		Hot Primary	
NPR	M=0.0	0.32	0.0	0.32	M=0.0	0.32	0.0	0.32
1.51			222	230			329	340
1.99	217		223	231	337		330	341
2.37			224	232			331	342
2.48	218	238	225	233	327,338,348		332	343
2.96	219	239	226	234			333	344
3.25			227	235			334	345
3.43	220		228	236	328,343		335	346
4.00	221		229	237	339		336	347

Mixer 4, Conf = 452.056, MAR=0.95, Hardwall, Mixer Exit Pressure Survey						
	Cold Primary			Hot Primary		
NPR	M=0.0	0.245	0.32	M=0.0	0.245	0.32
1.99	386	402				395
2.48	387	403	400	391	393	396
2.96	388	404				397
3.43	389	405	401	392	394	398
4.00	390	406				399

NPR	Mixer 4, Conf=422.076, MAR=0.95, 13mm SiC, Nozzle Exit Survey
2.48	204, 206, 207, 208, 209, 210
3.43	211, 212, 213, 214, 215, 216, 240, 241
NPR	Mixer 4, Conf=472.076, MAR=0.95, 13mm SiC, Nozzle Exit Survey
3.43	326, 350, 351, 352, 353, 354, 355, 356, 357, 358, 359

Mixer 8, Config 800.00, Isolated Mixer	
	Mach Number, Cold Primary
NPR	0.0
1.53	716,722,728
1.99	717,723,729
2.48	718,724,730
2.96	719,725,731
3.43	720,726,732
4.00	721,727,733

Mixer 8, Pen=92.5%, SAR=2.9, Hardwall, MAR=0.95								
	Conf 812.006, Flap=120"				Conf 852.006, Flap=160"			
	Cold Primary		Hot Primary		Cold Primary		Hot Primary	
NPR	M=0.0	0.32	0.0	0.32	M=0.0	0.32	0.0	0.32
1.51			153	161			618	608
1.99	148	171	154	162	603		619	609
2.37			155	163			620	610
2.48	149	172	156	164	604	626	621	611
2.96	150	173	157	165	605		622	612
3.25			158	166			623	613
3.43	151	174	159	167,168*,169**	606	627	624	614,615*,616**
4.00	152	175	160	170	607		625	617

Note: * Run 168, 615, 1091°R – 151°
** Run 169, 616, 1091°R + 149°

Mixer 8, Pen=92.5%, SAR=2.9, Porous Trays W/Hardwall Liner				
	Conf 842.006, MAR=.95, Flaps=120"			
	Cold Primary		Hot Primary	
NPR	M=0.0	0.32	0.0	0.32
1.51			703	691
1.99	699	711	704	692
2.37			705	693
2.48	689,700	712	706	694
2.96	701	713	707	695
3.25			708	696
3.43	690,702	714	709	697
4.00		715	710	698

Appendix B, HAM Model

Mixer 8, Pen=92.5%, SAR=2.9, 13mm SiC, MAR=0.95									
	Conf 822.006, Flaps=120"					Conf 872.006, Flaps=160"			
	Cold Primary		Hot Primary			Cold Primary		Hot Primary	
NPR	**M=0.0**	**0.32**	**0.0**	**0.20**	**0.32**	**M=0**	**0.32**	**0.0**	**0.32**
1.40					661				
1.51			125	664	133			574	560
1.99	120,656,672	143	126,684	665	134,662,677	556		575	561
2.37			127		135			576	562
2.48	121,657,673	144,670	128,685	666	136,663***,678	557	571	577	563
2.96	122,658,674	145	129,686	667	137,679,682	558	572	578	564
3.25			130		138			579	565
3.43	123,659,675	146,671	131,687	668	139, 140*, 141** 680,683	559	573	580	566,567*, 568**
4.00	124,660,676	147	132,688	669	142,681			581	569

Note: * Run 140,567, 1091°R – 151°
** Run 141,568, 1091°R + 149°
***Run 663, Problem with Acoustic Acquisition System.

Mixer 8, Pen=92.5%, SAR=2.9, 13mm Sic, MAR=0.95, With Chevrons								
	Conf 822.106, Flaps=120"				Conf 872.106, Flaps=160"			
	Cold Primary		Hot Primary		Cold Primary		Hot Primary	
NPR	**M=0.0**	**0.32**	**0.0**	**0.32**	**M=0.0**	**0.32**	**0.0**	**0.32**
1.51			529	519				541
1.99			530	520				542
2.37			531	521			550	543
2.48	517		532	522	539		551	544
2.96			533	523				545
3.25			534	524			552	546
3.43	518		535	525,526*,527**	540		553	547, 548***
4.00			536	528				549

Note: * Run 526, 1091°R – 151°
** Run 527, 1091°R + 149°
***Run 548, Vacuum System Off.

Mixer 8, Conf 852.056Pen=92.5%, Mixer Exit Survey						
	Cold Primary			Hot Primary		
NPR	**M=0.0**	**0.245**	**0.32**	**0.0**	**0.245**	**0.32**
1.99	628	644				637
2.48	629	645	642	633	635	638
2.96	630	646				639
3.43	631	647	643	634	636	640
4.00	632	648				641

Mixer 8, Nozzle Exit Survey	
NPR	**Conf=822.076, Pen=92.5%, SAR=2.9, 13mm Sic, MAR=0.95, Hot Primary,**
3.43	649,650,651,652,653,654,655
NPR	**Conf=872.076, Pen=92.5%, SAR=2.9, 13mm Sic, MAR=0.95, Hot Primary,**
2..48	589,590,591,592,593,594,595
3.25	596,597,598,599,600,601,602
3.43	582,583,584,585,586,587,588

Appendix B, HAM Model

Mixer 10, Config 1000.00, Isolated Mixer	
	Mach Number, Cold Primary
NPR	0.0
1.53	752,764
1.99	753,759,765
2.48	754,760,766
2.96	755,761,767
3.43	756,762,768
4.00	757,763,769

Mixer 10, Pen=85% ,BLR Conf=6								
	Conf 1012.006, Hardwall MAR=0.95				Conf 1022.006, 13mm SiC, MAR=0.95			
	Cold Primary		Hot Primary		Cold Primary		Hot Primary	
NPR	M=0.0	0.32	0.0	0.32	M=0.0	0.32	0.0	0.32
1.51			438	430			463	453
1.99	425	444	439	431	449		464	454
2.37				432			465	455
2.48	426	445	440	433	450	471	466	456
2.96	427	446	441	434	451		467	457
3.25				435			468	458
3.43	428	447	442	436	452	472	469	459,460*,461**
4.00	429	448	443	437			470	462

Notes: * Run 460, 1091°R – 151°
** Run 461, 1091°R + 149°

Mixer 21, Config 2100.00, Isolated Mixer	
	Mach Number, Cold Primary
NPR	0.0
1.53	770,776
1.99	771,777
2.48	772,778
2.96	773,779
3.43	774,780
4.00	775,781

Mixer 21, Pen=100%, NRA						
	Conf 2112.006, Hardwall MAR=0.95			Conf 2122.006, 13mm Foam Metal, MAR=0.95		
	Hot Primary			Hot Primary		
NPR	0.0	0.245	0.32	0.0	0.245	0.32
1.00					101 *	108*
1.51	407	413	419	89	95	101
1.99	408	414	420	90,110,115	96	102
2.48	409	415	421	91,111,116	97	103,104
2.96	410	416	422	92,112,117	98	105
3.43	411	417	423	93,113,118	99	106
4.00	412	418	424	94,114,119	100	107

* Noise Floor

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (*Leave blank*)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	February 2005	Final Contractor Report

4. TITLE AND SUBTITLE

Gen 2.0 Mixer/Ejector Nozzle Test at LSAF June 1995 to July 1996

5. FUNDING NUMBERS

WBS–22–714–09–46
NAS3–27235

6. AUTHOR(S)

L.D. Arney, D.L. Sandquist, D.W. Forsyth, and G.L. Lidstone

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

Boeing Commercial Airplane Company
Division of the Boeing Company
Seattle, Washington 98124–2207

8. PERFORMING ORGANIZATION REPORT NUMBER

E–14804

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

National Aeronautics and Space Administration
Washington, DC 20546–0001

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

NASA CR—2005-213334

11. SUPPLEMENTARY NOTES

This research was originally published internally in April 1997. Project Manager, Mary Jo Long-Davis. Responsible person, Diane Chapman, Ultra-Efficient Engine Technology Program Office, NASA Glenn Research Center, organization code PA, 216–433–2309.

12a. DISTRIBUTION/AVAILABILITY STATEMENT

Unclassified - Unlimited
Subject Categories: 01, 02, 05, and 07 Distribution: Nonstandard

Available electronically at http://gltrs.grc.nasa.gov

This publication is available from the NASA Center for AeroSpace Information, 301–621–0390.

12b. DISTRIBUTION CODE

13. ABSTRACT ***(Maximum 200 words)***

Testing of the HSCT Generation 2.0 nozzle model hardware was conducted at the Boeing Low Speed Aeroacoustic Facility, LSAF. Concurrent measurements of noise and thrust were made at critical takeoff design conditions for a variety of mixer/ejector model hardware. Design variables such as suppressor area ratio, mixer area ratio, liner type and thickness, ejector length, lobe penetration, and mixer chute shape were tested. Parallel testing was conducted at G.E.'s Cell 41 acoustic free jet facility to augment the LSAF test. The results from the Gen 2.0 testing are being used to help shape the current nozzle baseline configuration and guide the efforts in the upcoming Generation 2.5 and 3.0 nozzle tests. The Gen 2.0 results have been included in the total airplane system studies conducted at MDC and Boeing to provide updated noise and thrust performance estimates.

14. SUBJECT TERMS

HSCT; LSAF; Mixer/ejector; Jet noise; Aeroacoustic; High speed civil transport; Propulsion; Nozzle; Analysis

15. NUMBER OF PAGES

133

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	